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INFECTIOUS HEPATITIS AND WATER EVALUATION AND
CHLORINATION

George W. Powell, et al

Department of the Air Force
New York 09224

April 1968



THE U.S. LOGISTICS GROUP DETACHMENT 36

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EPIDEMIOLOGY

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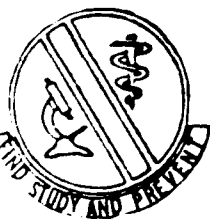
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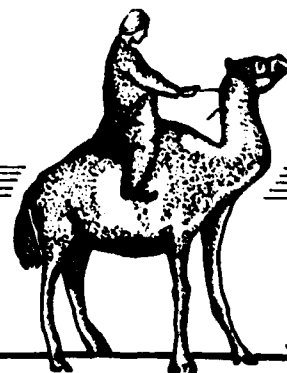
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FOREWORD

This publication is prepared and disseminated for the specific purpose of providing epidemiological information within the general scope of the Epidemiological Services of the USAF Aerospace Medicine Program, AFM 161-2, dated 1 October 1962 and AFR 161-12, dated 10 November 1964. The use of this information for purposes other than as specified therein relieves the authors and the USAF of responsibility or obligation. Qualified requestors may obtain copies of this publication from DDC.

This work was accomplished under TUSLOG Detachment 36 (Epidemiology) Project number 66-6, the purpose of which is to conduct field studies of all those epidemiological, biological and sanitary facets of infectious hepatitis which might lead to morbidity reduction. This study has been an activity of this unit since its formation in 1952. (see references 1 through 4)

The authors are especially indebted to Shih L. Chang MD, USPS. The authors also express their indebtedness to Major John A. Klotsko USAF, MSC, TSgt William D. Phelps USAF, SSGT William K. Nix USAF and others of Detachment 36.

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DEPARTMENT OF THE AIR FORCE
TUSLOG DETACHMENT 36 (USAF)
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EPIDEMIOLOGY

Report No. 68-5

INFECTIOUS HEPATITIS AND
WATER: EVALUATION & CHLORINATION

APRIL 1968

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PROJECT NO. 66-6

DEPARTMENT OF THE AIR FORCE
TUSLOG DETACHMENT 36(USAF)
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EPIDEMIOLOGY

INFECTIOUS HEPATITIS AND WATER:
EVALUATION AND CHLORINATION

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DEPARTMENT OF THE AIR FORCE
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I PURPOSE

The purpose of this paper is to summarize our conclusions from several investigations of hepatitis, to provide a guide for those with responsibility regarding water supplies and to attempt to establish "a priori" a rule of thumb for the lowest practical water chlorination levels to prevent water-borne infectious hepatitis among personnel to whom the US Air Forces overseas provide preventive medical services and medical care. That is, to establish a safe point between the conflicting parameters of (a) a virucidal action of chlorine in water which cannot be measured and (b) water taste/acceptability which can only be measured subjectively.

The US National Academy of Sciences-National Research Council has formally stated to the US military services regarding broad overall military policy that "the NAS-NRC do not consider maintenance of a residual (in the distribution system) a satisfactory substitute for good design, construction and supervision of a water system" (Appendix V⁶⁴). We agree, but, as the NAS-NRC recognized, local difficulties may modify this. They stated "the best policy to follow is to decide only after all the factors pertinent to the particular local situation have been carefully reviewed." Some of these factors particularly regarding a Mediterranean area are reviewed herein.

A variable involved in the conflicting parameters mentioned is the quality of the source water prior to chlorination. Hence, we deal at some length with the factors that must be investigated in order to evaluate the quality of source water for our purposes. Other variables are the treatment (other than chlorination) applied to the water and contamination within the water system. This paper deals largely with relatively poor quality waters that receive little or no treatment other than chlorination.

II INTRODUCTION

Infectious hepatitis is undoubtedly spread at times by food^(65,87), including food handlers⁽⁴⁾, through direct contact⁽⁵⁾ (particularly between children) and perhaps, rarely by flies^(6,7,8,9). It has long been, and is still, recognized^(10,11) that, in the military situation, water transmission and the resistance of the virus are points of primary interest. A study and review of the factors involved in water transmission are appropriate at this time due to:

- a. The continuing high incidence of hepatitis among US personnel in some overseas areas.

b. The continued USAF operation in areas where much of the water is highly polluted bacteriologically. In view of primitive sewage disposal methods, this contamination is probably more often of human origin than in U.S.

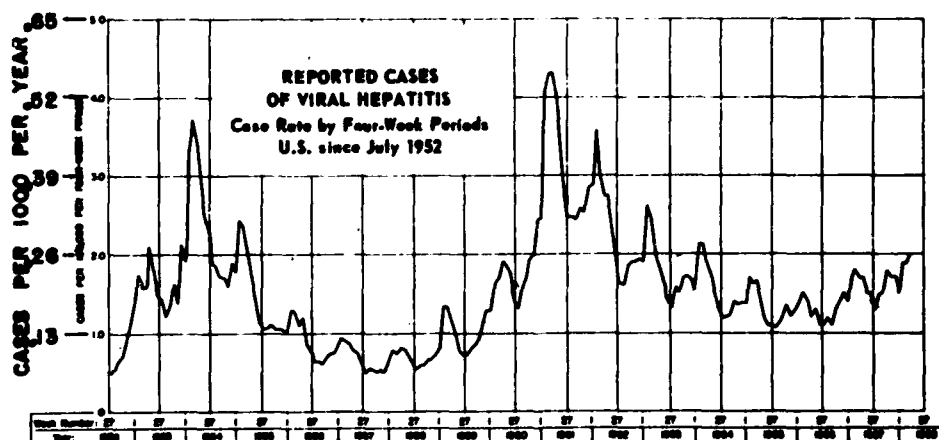
c. The implication that high USAF overseas rates may be due in part to the "temporary nature" of overseas base water treatment. Partly in order to conserve funds, base treatment of clear water (obtained from as little as 8 feet below the ground surface) is sometimes limited to chlorination. This has been true even though some bases have been used by US forces for up to 10 years⁽¹²⁾.

An attempt is thus made to provide a review and interior study in order to assist in future base water supply planning, design and operation and in the epidemiological investigation and prevention of future hepatitis morbidity.

III MAGNITUDE OF THE PROBLEM

Infectious hepatitis morbidity has been an increasing problem in the U.S. for a number of years. In recent years the peak reported U.S. incidence occurred in 1960-61, (Figure 1) (13).

FIGURE 1
Morbidity and Mortality Weekly Report

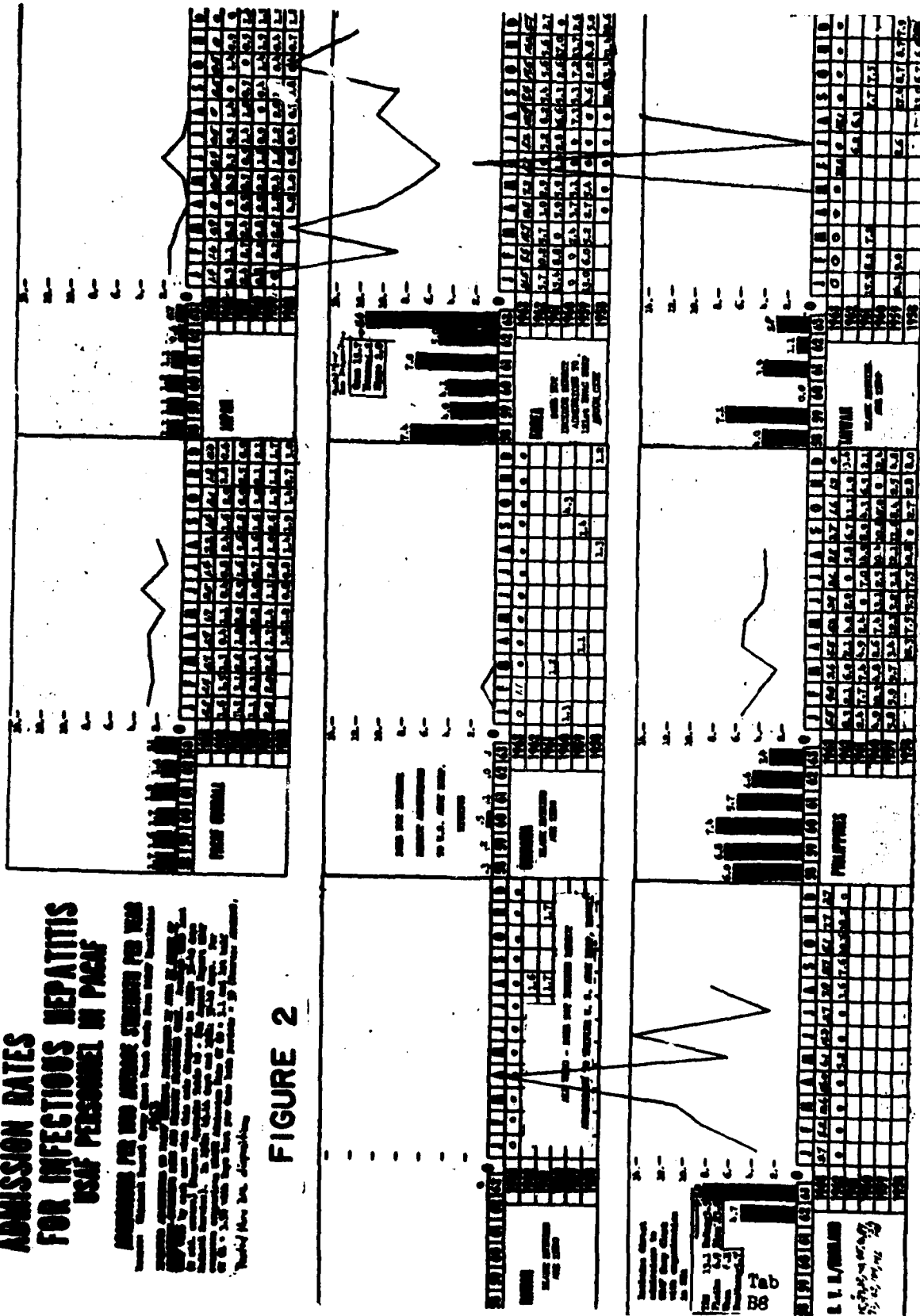


In the USAF overseas this disease has been a major cause of communicable disease morbidity and non-effectiveness.⁶⁶ The yearly admission rates during 1958-63 for USAF personnel in Japan varied between 0.6 and 1.2 admissions per 1000 strength per year (Figure 2). In the UK, 1963-66, the yearly rate varied from 0.3 to 1.3 and monthly rate once reached 5.0 (Figure 3). During this period the 4-weekly-U.S.-civilian rates varied between 0.07 and 0.56 cases per 1000 per year. The higher rates in Japan and UK could well be explained on the basis

ADMISSION RATES FOR INFECTIONS HEPATITIS BY PERSONNEL IN PACAF

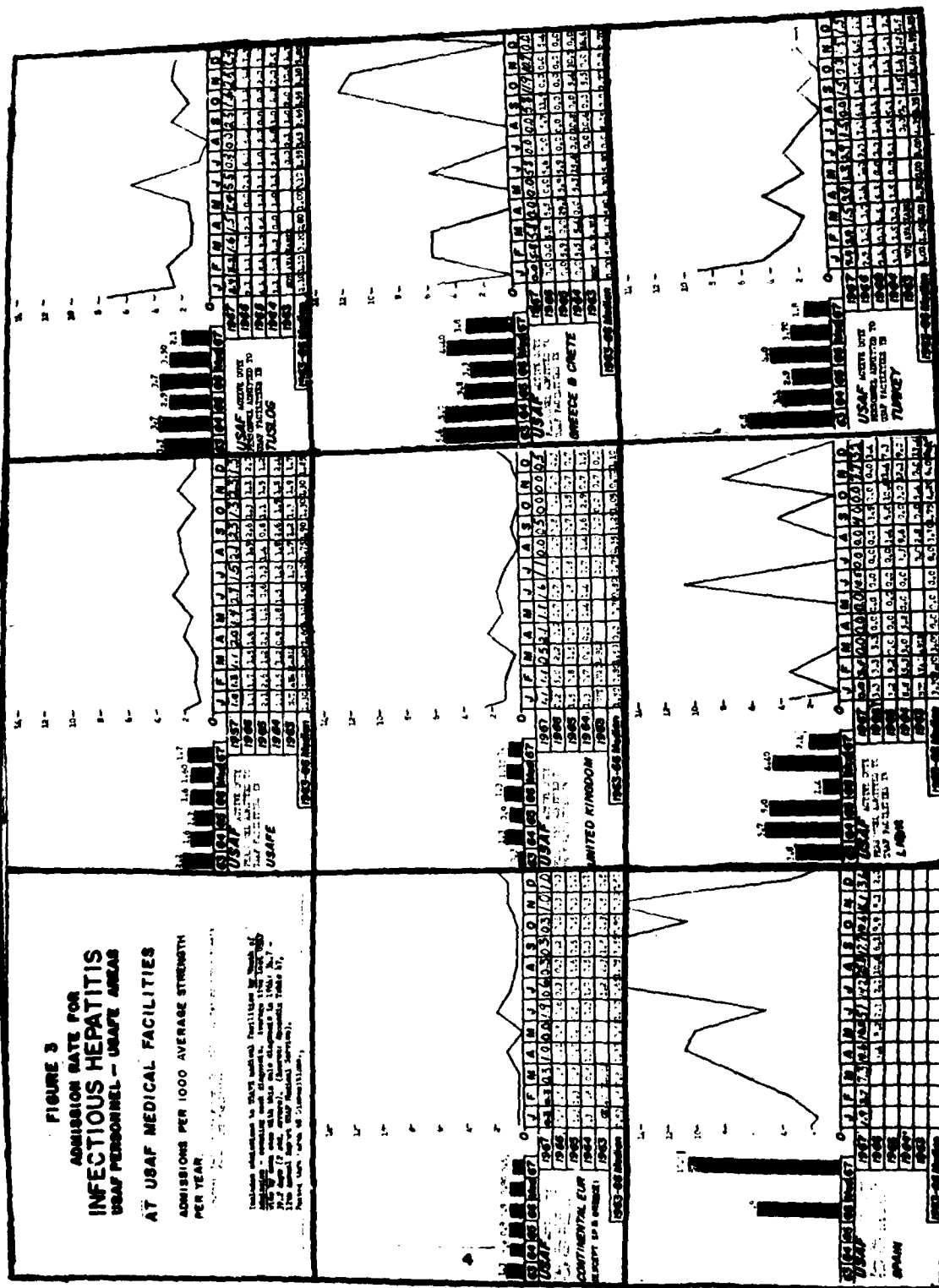
ADMISSION RATES FOR INFECTIONS HEPATITIS BY PERSONNEL IN PACAF
 The following table shows the admission rates for infections hepatitis by personnel in PACAF from 1958 to 1960. The rates are shown for each month and for the total year. The rates are based on the number of personnel in PACAF and the number of admissions for infections hepatitis.

FIGURE 2



**ADMISSIONS PER 1000 AVERAGE STRENGTH
PER YEAR.**

Inclusion statements to show national participation by month of reporting - continue each statement. Increase from 1944-1945. City of New York with this also diagnosed in 1944, 1947-1949, 1950, 1951, 1952, 1953, 1954, 1955, 1956, 1957, 1958, 1959, 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2



of more complete reporting due to admission of almost all overseas obvious military cases to military hospitals.

However, Figures 2 through 4 demonstrate that in other less-well-developed overseas areas, USAF rates have been much higher. The highest ~~are~~ yearly USAF rate shown is for Korea, 1963, 11.6 per 1000 strength. The actual final 1963 Korea rate was 12.1. The highest individual air base yearly rates shown were in 1963: Osan, Korea, 15.7 and Tan Son Nhut, RVN 13.1. Far East rates have since been considerably altered by the widespread use of gamma globulin prophylactically and rigorous sanitary measures ⁽¹⁴⁾.

USAF rates throughout Europe and the Middle East (U.S. Air Forces in Europe-USAFE) have been lower but have continued at endemic levels. That similar or higher rates occur among dependents is seen in Attachments 1 and 2. Gamma globulin in the USAFE areas has, in general, only been used for the immediate contacts of cases.

Total disease incidence data is more difficult to obtain and is less reliable. Individual USAF bases vary between each other, and with time, regarding whether or not hospitalize mild and moderate cases. Therefore minor rate differences between bases, or with time, have little significance. Comparisons between rates in USAF personnel and rates among dependents are almost meaningless. Nevertheless, the fact of admission to hospital gives a valid "slice of the problem" for comparing large variations and sometimes for comparing large groups of bases. It is also, in general, the most important slice.

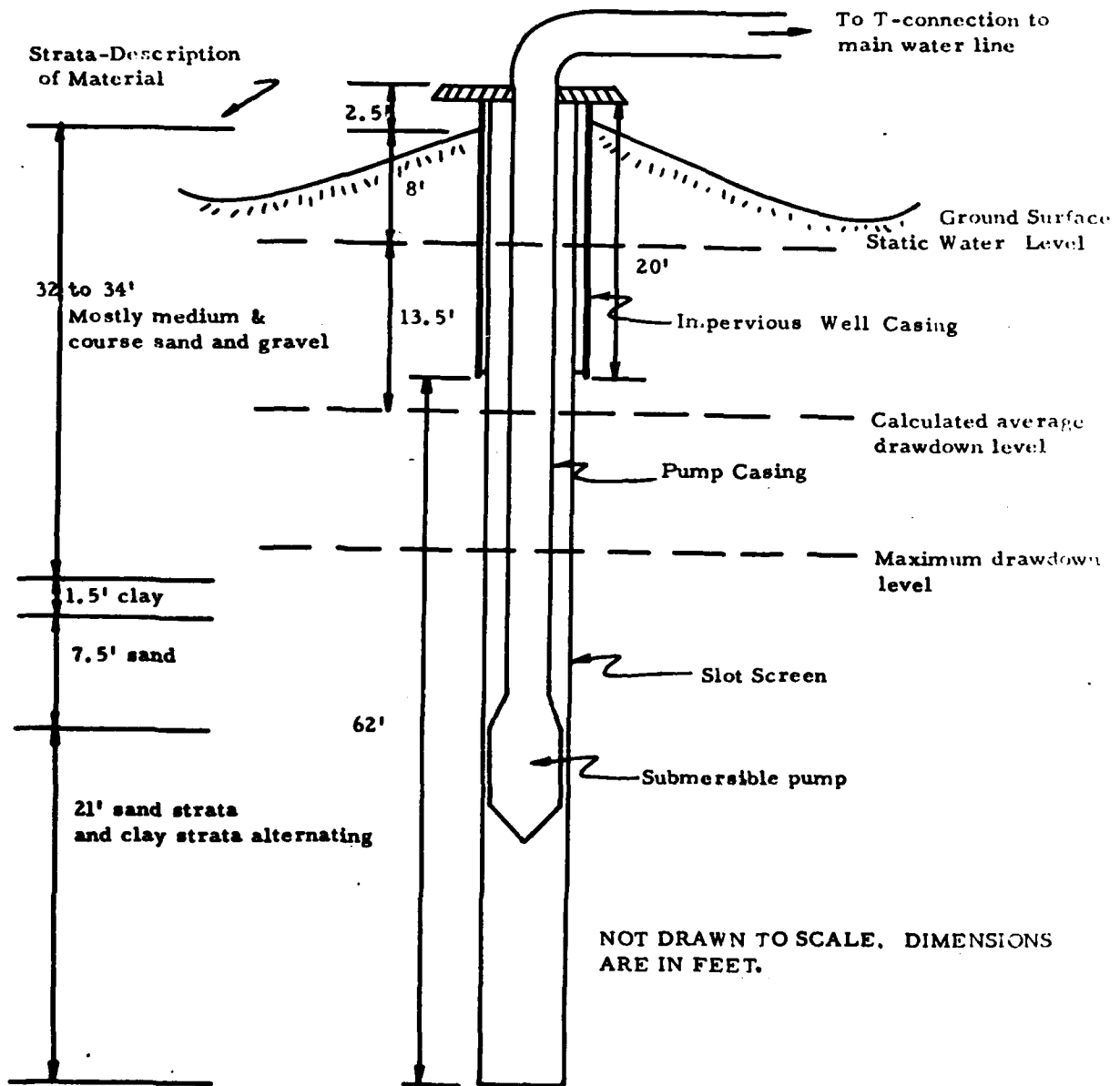
In 1964 the average USAF inpatient with infectious hepatitis with no other diagnosis lost 34.7-39.2 days (\pm 2 standard errors) from duty in the hospital ⁽¹⁵⁾. This disease has thus been a source of major concern to the USAF overseas and many investigations of outbreaks or of high endemic incidence have been conducted. Many of these have either incriminated water supplies or caused them to be suspect ^(3,12,16). Recently 25 civilian outbreaks were summarized (Atch 3) ⁽⁸⁾. It will be noted that the bulk of the cases arose from public chlorinated, surface water supplies. The largest single outbreak was in India. The data show that cross-connections were also responsible for some outbreaks.

Our findings in the E. Mediterranean/Middle East area serve as a starting point to discuss overseas water transmission factors and control measures.

IV WATER SOURCE

The majority of USAF bases in Turkey, Greece, Pakistan and Libya obtain their water supplies from ground water sources and treat the water by chlorination only ^(12,16-38). Many wells are located off-base in river flood basins in soil strata composed of sand, gravel and clay. An example of a well of this type is shown in Figure 5. In this case, the static water level is approximately 8 feet

FIGURE 5
CROSS SECTION OF WELL WITH
SUBMERSIBLE PUMP



below the ground surface and the well is imperviously cased to only 20 feet below the ground surface (39). Bacteriological analyses of some of the water sources of this type have shown contamination by coliform bacteria (12, 19, 20, 24, 29, 37). Personnel who work and/or live in cities or towns often are supplied with domestic water which usually contains coliform organisms. When supplied to a building utilized for USAF duty or by U.S. dependents (e.g. hospitals, schools, commissaries, etc.) water is often chlorinated at the building.

V WATER TREATMENT AND DISTRIBUTION

U.S. military medical services have a monitoring and advisory responsibility (40) to assist engineering personnel in preventing water-borne disease. These responsibilities and methods for carrying them out are outlined in Appendix II. Particularly important are the following considerations:

1. Cross-Connections

Cross-connections are recognized hazards but we have found that it is not only the hidden cross-connections out in the distribution system that must be sought. Valved cross-connections are not uncommon in base distribution systems and water plants. These are often purposely built into the system in order to provide "quick-surge" for fire fighting.

A flow diagram of a base water plant with cross-connections for this purpose is shown in Figure 6. Such cross-connections are often concealed and require careful study and understanding. This can often be best achieved by preparation of such a flow diagram. In the Figure 6 case, raw water from the well sources is pumped into the top of the ground storage tanks. Some of the water is then chlorinated and pumped into the top of the elevated storage tank. The chlorinated water flows by gravity from the bottom of the elevated storage tank to the water plant and distribution system. Cross-connections are noted at valves x, y, and 13. If the valves are always closed, cross-contamination will not occur. Valves x and y would be opened only when fire pumps are used to pump water through the distribution system in case of fire or fire-pump check. When this is done, raw water is pumped into the distribution system thus contaminating the water pipes.

Continuity of positive pressure throughout the distribution system must also be assured. Since some leaks in sewage and water systems will, inevitably be present, if pressure in the water systems falls to near that in the sewer system, it is likely that we have in effect a cross-connection. This is also true if the water system pressure falls to that of a hydrostatic head equal to the depth of the water pipe underground.

2. Chlorine Disinfection

An understanding of chlorine reactions, terminology in common use, and the limitations of available quantitative tests for chlorine in water is essential for responsible water plant personnel and medical service monitors. See Appendix I. Important points to keep in mind during the ensuing discussion are:

FIGURE 6
SCHEMATIC DIAGRAM OF WATER PLANT
AND STORAGE TANKS

Three cross connections exist at valve locations 13, x, and y. If valves 13, x, and y are always closed, cross contamination will not occur. Valves x and/or y would be opened only when fire pumps are used either to pump water to the storage tanks (i.e. used as back up for filling pumps) or to pump water through the distribution system in case of fire or fire pump maintenance check.

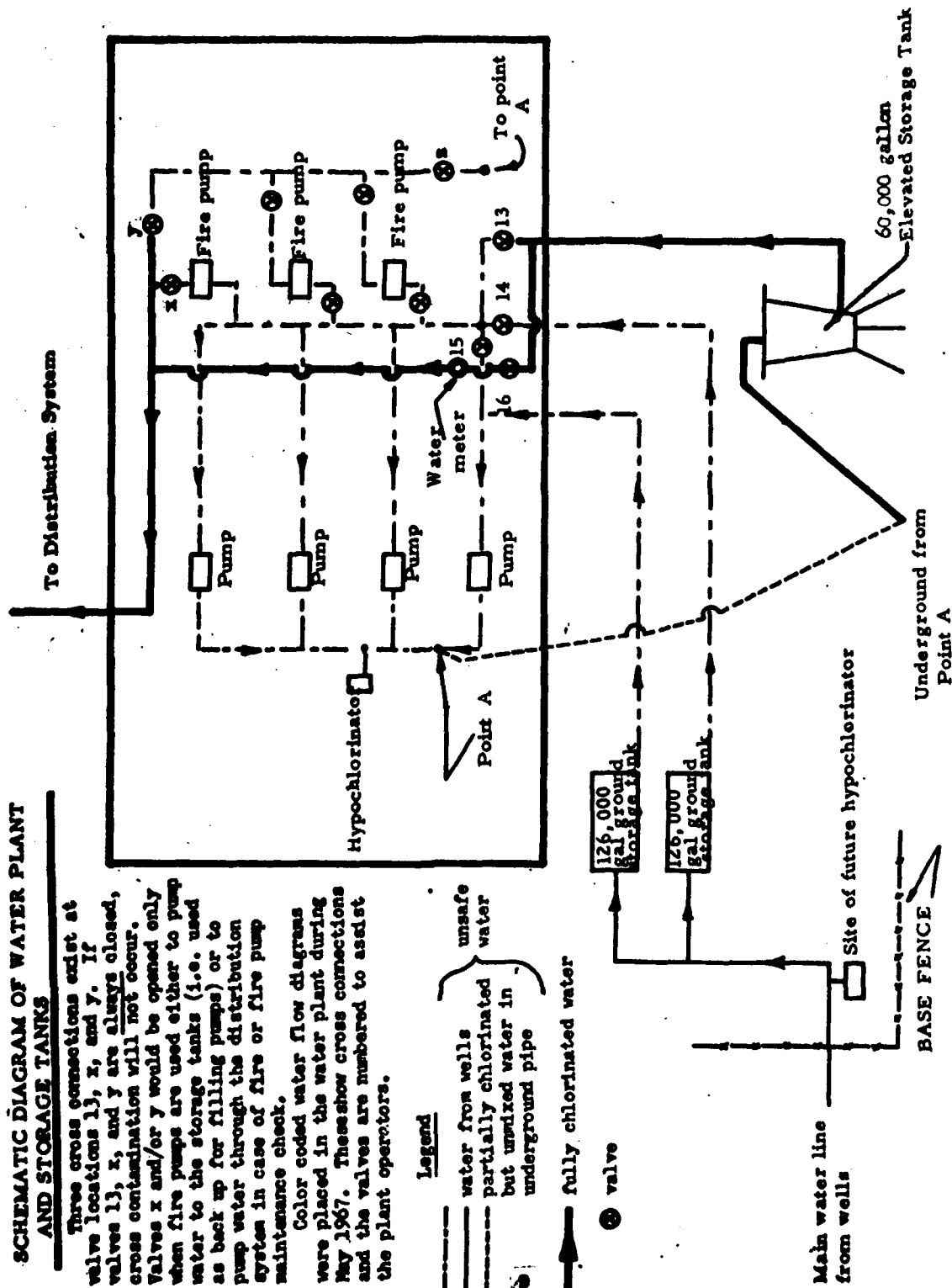
Color coded water flow diagrams were placed in the water plant during May 1967. These show cross connections and the valves are numbered to assist the plant operators.

Legend

--- water from wells
--- partially chlorinated water
--- but mixed water in underground pipe

→ fully chlorinated water

● valve



a. Any increase in concentration of a disinfectant decreases the time required to kill, for example, 99% of a microorganism species present, if pH and the temperature of the water are constant.

b. Free available chlorine ($\text{HOCl} + \text{OCl}^-$) can be quantitatively measured with accuracy in the field. Quantitative measurements of either one of these cannot be accomplished in the field but can be determined if the pH and temperature are measured.

3. Contaminated System Disinfection

We have frequently found that native employees fail to follow USAF policy regarding disinfection of units of the water supply system following construction or repair. USAF worldwide policy requires scouring and flushing by water with "a velocity of at least 3 feet per second" afterwards "each unit of the system must be thoroughly disinfected before it is placed in operation". Recommended chlorine dosages are 50 ppm for pipes and tanks, 100 ppm for filters and 150 ppm for wells (41).

As we have seen (Appendix 1), a dosage of 150 ppm does not assure any free available chlorine residual i.e., does not assure disinfection. Therefore, policy guidance goes on to state, continue adding chlorine "until water discharging at other end of section contains desired residual chlorine" and, when using hypochlorite solution, add it until the "chlorine residual is about 50 ppm." Assuming that all of this "chlorine residual" might be in the form of monochloramine and that "about" is liberally interpreted to mean 40 ppm, 99% of E. coli would probably be killed in 2-3 minutes at 0-6°C. Presumably and hopefully the time taken to add chlorine, fill the system, test and retest, would be long enough so that, by the time 40 ppm was found, there would have already been sufficient contact time to have used up most of the chlorine demand. Policy provides thereafter for the chlorinated water to "remain in the section for 24-48 hours".

4. USAF Continuous Chlorination Policy

Most ground water supplies to bases in the Middle East are at pH 7-8 and temperature 0-20°C. Of the two variables in the equation: $c^n t = K$ (Appendix 1) for chlorine, the contact time (t) is determined largely by existing tank construction (12) (see Appendix III) i.e. additional contact time can only be achieved at relatively great construction expense. Contact time is established in policy as described below. Only disinfectant concentration (c) is amenable to inexpensive change. One exception is the situation described in Section V para 1 and Figure 6 where the chlorinator can be moved ahead of additional in-place tanks.

The USAF worldwide policy regarding continuous chlorination of water at military installations is that "A measurable chlorine residual after a 30-minute contact period in the system or in a closed sample bottle will be maintained at all times in those parts of the potable water distribution system under constant circulation. This does not apply to water directly supplied by the appropriate state health authority.... (or) if, following chlorination, the water is stored for long periods in properly protected distribution reservoirs." (40)

"Under ordinary field conditions, a chlorine residual of 1.0 ppm after 10 minutes of contact time is required in all drinking water. In areas where amebic dysentery, infectious hepatitis or schistosomiasis are prevalent, the chlorine residual must be increased to 2.0 ppm or more after 10 minutes of contact time. In any case, the water should not be used until 30 minutes have elapsed after the addition of the chlorine" (42).

HQ TUSLOG (the USAF command in the E. Mediterranean and Middle East under HQ US Air Forces Europe) in Dec 1966 wired to all their Directors of Base Medical Services, "The following procedures are recommended: A. A minimum free available chlorine residual of 1.5 ppm will be maintained in all military controlled water systems. (Complete base distribution systems, treatment plants at water pick-up points, hand chlorinated systems, etc.) B. All personnel obtaining water from other than military controlled systems should treat their water. Five to seven drops of chlorox per gallon of water normally provides a safe water product. The commercial home filters do not, repeat do not, remove virus. This water should be treated."

5. Continuous Chlorination-General

Continuous chlorination is essential in dealing with water supplies of the type described in Section IV above. At Middle East bases this is usually accomplished by the addition of chlorine in the form of calcium hypochlorite because of its concentrated form and ease of handling. Determination of actual contact time is therefore a matter of great importance. Methods of accomplishing this in a common set of circumstances is given in Appendix III.

The cost of chlorination of water supplies is relatively inexpensive (for chemical e.g. \$75. for 20 million gallons) when compared to initial construction of pretreatment facilities such as those for aeration, coagulation, settling and filtration (43). (See Appendix IV). Also, costs of increased maintenance and additional chemicals must be considered.

To reduce the likelihood of an infectious hepatitis or other disease outbreak from accidental opening of cross-connection valves (or from failure to super-chlorinate after they are opened), the entire water supply should be chlorinated. Using the Figure 6 example, a hypochlorinator with adequate mechanical, operational, testing and administrative structure could be installed at a point in the main water line from the wells so that all the raw water is chlorinated before it enters the two ground storage tanks.

6. Chlorination Equipment

Automatic chlorination equipment, especially when chlorination is the sole barrier, must perform constantly. At one US dependents school supplied by contaminated domestic city water which was then chlorinated by a hypochlorinator at the school, we found zero chlorine residual. The old hypochlorinator ceased operation sometime before the once-a-day, 6-days-a-week inspection by the civilian contractor. It was found that, of 14 hypochlorinators in the area, about 1/4

were malfunctioning at any one time. All were old. A hypochlorinator costs about \$700.00.

7. Operator Proficiency

Maintenance and operation of base water supply systems are often accomplished by untrained personnel. At one USAF station there was some doubt as to the testing rigor which preceded the recordings of hourly chlorine determinations by base Civil Engineering personnel. All readings recorded for a period of a month were 2 ppm ⁽¹²⁾.

At another station, while visiting the water plant, it was noted that the operator had not turned on the chlorinator even though water was being pumped to the distribution system. When questioned about the situation, he immediately turned it on and stated that he had intended to do so anyway. The container holding the hypochlorite solution was low and the suction hose was almost exposed to the air. The operator stated he had not noticed this ⁽³³⁾.

At another station, water samples taken from the distribution system for bacteriological analysis were positive for coliform organisms. The samples were taken from water lines that had not been superchlorinated after initial construction ⁽⁵⁾.

The effectiveness of chlorination is dependent on adequate dosage, testing and operation which, in turn, are heavily dependent on competent and reliable operators.

VI WATER CONTAMINATION AND BACTERIOLOGY

As we have seen for microorganisms in general, the inactivation of human enteric viruses by chlorine is affected by temperature, pH, disinfectant concentration, contact time and virus species ^(44, 45, 46). Contact time and concentration of HOCl, OCl⁻, monochloramine, etc. in water required to kill infectious hepatitis (IH) virus is not known because, other than in human volunteers, there is as yet no proven way of demonstrating its presence or inducing it to multiply. It is known that complete inactivation of many enteric viruses is not achieved by the usual conditions for killing bacteria in water.

Figure 7 is a plot of $c^n t = K$ curves on logarithmic paper for various halogen disinfectants and organisms. Lines 1, 2 and 3 are for the effect of HOCl on *E. coli*, a poliomyelitis virus and Coxsackie A2 enterovirus. Comparison of lines 1 and 3 demonstrates the resistance of Coxsackie A2.

IH virus is often cited for its resistance to chlorine ⁽⁴⁷⁾. The few reported findings for individual points on the $c^n t = K$ curve for IH virus vary widely. This is in part due to the literature containing terminology variance or antiquated testing regarding chlorine concentration. Point A, Figure 7 is at 15 ppm for 30 min. This is cited as being beyond the breakpoint of the particular IH contaminated water

tested and as causing "definite attenuation" of IH virus in "residual chlorine" (47). Much of this residual may have been chloramines. Note how far point A is to the right of lines 3 and 4.

At any rate such a line for IH virus cannot now be drawn. What is the next best determinant for disinfectant concentration and contact time? The use of a resistant virus as an indicator organism would obviously be most desirable and has been strongly recommended (48). However, such a virus would be likely to be more susceptible to disinfectant than IH virus and no easy and practical method for routine viral recovery from water and subsequent assay has yet been developed.

1. Indicator Bacteria

Therefore, bacteria must still be relied upon as "indicator organisms" i.e. their presence is used as an indicator as to whether:

- a. Source water is contaminated/polluted.
- b. Treated water has been adequately treated.

The indicators of pollution finding most general acceptance today are the coliform group and the fecal streptococci. Both groups require careful interpretation as to their actual significance. The coliform group includes (49):

- a. Escherichia coli. E. coli are found and multiply in many places. Those which inhabit, or come from, human or animal intestines are called fecal coli. Since fecal coli do not survive in water for as long a time as other numbers of the coliform group, (49, 50), their presence in water is considered indicative of recent fecal contamination or recent pollution with soil runoff-water.
- b. Aerobacter species (e.g. A. aerogenes and A. cloacae). These occur in fecal discharges (though usually in smaller numbers than E. coli); on different plant species; and in packing and sealing materials used for pipelines and valves.
- c. Various plant pathogens (e.g. Erwinia sp., Pseudomonas sp.)
- d. Organisms about which very little is known regarding their natural habitat(s).

Although the coliform group has been widely preferred as an indicator by many workers through the years, a great deal of interest also centers on the fecal streptococci as indicators of fecal pollution in water. Included in this group are:

- a. The enterococci (49, 51). (e.g. Streptococcus faecalis, Streptococcus durans)
- b. Streptococcus faecium, S. bovis, S. equinus and other strains meeting the criteria of Lancefield's Group D Streptococci (49, 52, 53).

These organisms are indicative of fecal pollution as they are more consistently associated with feces of warm-blooded animals than the fecal coli. Thus their use in water microbiology tends to reduce the problem of determining fecal vs. nonfecal origin (52). They do not multiply in water and cause over-growths as is sometimes the case with the coliforms. The density of fecal streptococci recovered therefore is in general equal to or less than the density of fecal pollution that was originally discharged into the water. (54).

Recent reports in the literature, however, demonstrate the association of organisms similar to the fecal streptococci with various types of vegetation. These could be introduced into water sources from food industry wastes or stormwater runoff (49, 55). This has complicated the interpretation of the presence of streptococci and could cause misleading results in the analysis of certain waters. Much more information is still needed on detection procedures, sources, survival and significance of the streptococci in different types of water.

2. Is Contamination Human or Animal? Source of Indicator Bacteria

If a ground water source is bacteriologically sterile it seems that it is less likely to contain IH virus. As we have seen in overseas areas, ground water is often bacteriologically contaminated. IH virus is not known to occur in animal feces. If a bacteriologically contaminated ground water source could be shown to have acquired its bacteria entirely from non-human sources, it seems likely that it would contain no IH virus. No entirely satisfactory method exists for distinguishing coliforms as to their human or animal origin.

It appeared from some studies that perhaps those coliforms that produced gas from lactose at 44.5°C (as well as at the standard 35°C) were likely to be from humans. They have since been shown to be usually fecal, but not necessarily human. The test was originally conceived by Eijkman in 1904⁽⁵⁶⁾ and has been the subject of a number of papers since then^(57, 58, 59). The modification of the tests as described in Standard Methods⁽⁴⁹⁾ will allow estimates of the density of both fecal and non-fecal coliforms in water, and thus, give information as to the remoteness, both in distance and time, of this pollution. This test will not eliminate the possibility that polluted water may contain human fecal contamination.

At present, it is possible to estimate a source of fecal contamination, i.e., human or animal, with careful quantitative studies of each streptococcal species recovered from the water, but, the methodology involved is tedious^(60, 61). Reports have also been published on the use of inhibitory agents (e.g. sodium azide) for differentiating streptococci of human and animal origin with varying degrees of efficiency^(53, 54, 62). These also will not eliminate the possibility of human fecal contamination.

A third method which will distinguish between the contribution of human versus animal wastes in water is being evaluated currently^(55, 58). This method utilizes the recognized procedures, such as those in Standard Methods⁽⁴⁹⁾, to obtain both the fecal coliform and fecal streptococci densities from the same water sample point, from which a ratio is derived. It has been found that, because of the density relationships of these organisms typically observed (in human and various animals feces, commercial and domestic wastes, and stormwater discharges), a ratio greater than 4 to 1 (coliform to streptococci) usually means pollution from domestic wastes. These contain a large proportion of human body wastes. Pollution from meat packing and dairy plants, poultry and livestock, or stormwater runoff normally results in ratios of 0.7 to 1.0 or lower. These ratios, as well as being influenced by several environmental factors, cannot be used (even when below 0.7) to eliminate the possibility of human contamination. Therefore, the possibility of

the presence of IH virus cannot be eliminated in a potential drinking water source. Nor has the use of the method been applied to the evaluation of treated water, wherein to obtain some estimate of human fecal contamination, one must resort to the enumeration of specific streptococci present.

The fecal streptococci, then, seem to be more useful than the coliforms for indicating the type of pollution occurring in surface waters and other untreated or inadequately treated water sources and systems. In a study of the Izmir, Turkey water system, Det 36 Report 63-2⁽³⁰⁾, the fecal streptococci were thought to be more sensitive indicators of pollution than were the coliforms. Fecal streptococci are of no greater value than the coliform group for examination of adequately treated water⁽⁵⁴⁾.

VII HOW MUCH CHLORINE?

As mentioned in section VI, above, Figure 7 is a logarithmic graphpaper plot of $c^{\text{Pt}}=K$ for numerous conditions. Clark and others⁽⁴⁴⁾ report that, at 0-6°C, Polio-myelitis Type 1 and Coxsackie A2 viruses (lines 2 & 3) are considerably more resistant than Escherichia coli (line 1) to HOCl. Point A is Neefe's finding of 15 ppm for 30 min. for IH virus in "residual chlorine."⁽⁴⁷⁾ Following a summer camp outbreak of infectious hepatitis, Neefe again stated⁽⁶³⁾, application of 1 ppm of "residual chlorine" in the absence of pretreatment did not eliminate the virus. (pH not given)

We believe the answer to "How much chlorine?" in overseas high-IH-incidence areas (assuming no cross-connections and rigorous regard for superchlorination requirements) is: enough so that, at the treatment site, there is always 0.4 ppm HOCl after 30 minutes contact time if the source water does not contain coliforms and 0.6 ppm if it does. Additionally, if coliform organisms are found in the distribution system, 0.4 ppm HOCl must be maintained throughout the active system but a one-time superchlorination should be tried. This is in consonance with the NAS-NRC statement regarding residuals in the distribution system (Appendix V)⁽⁶⁴⁾. Our argument for cited levels at the treatment point is four-pronged, viz:

a. On Figure 7 (before photoreduction) there was 2.9cm between the point on line 1 (1 ppm, 99% kill E. coli in HOCl) and point B. Point B is the point (1 ppm, 99% kill of E. coli in iodine). There is some logic for assuming that a similar difference might exist between HOCl and I₂ for any microorganism. Coxsackie A virus is resistant. We know the response of Coxsackie A9 virus in I₂ at 5°C. This is line 6 on Figure 7⁽⁴⁴⁾. If we measure 2.9cm along the 1 ppm line from line 6, we are at the point labeled C. This may represent the response of Coxsackie A9 virus to 1 ppm HOCl.*

Dashed lines 7 and 8 are extrapolations from point C at slopes $n=1$ and $n=1.5$ respectively. One of these lines might be expected to approximate the actual line for Coxsackie A9 virus in HOCl at 5°C. IH virus might be expected to behave similarly since it is also a resistant virus. Thus at $n=1.0$ and 30 minutes contact time, 15 ppm

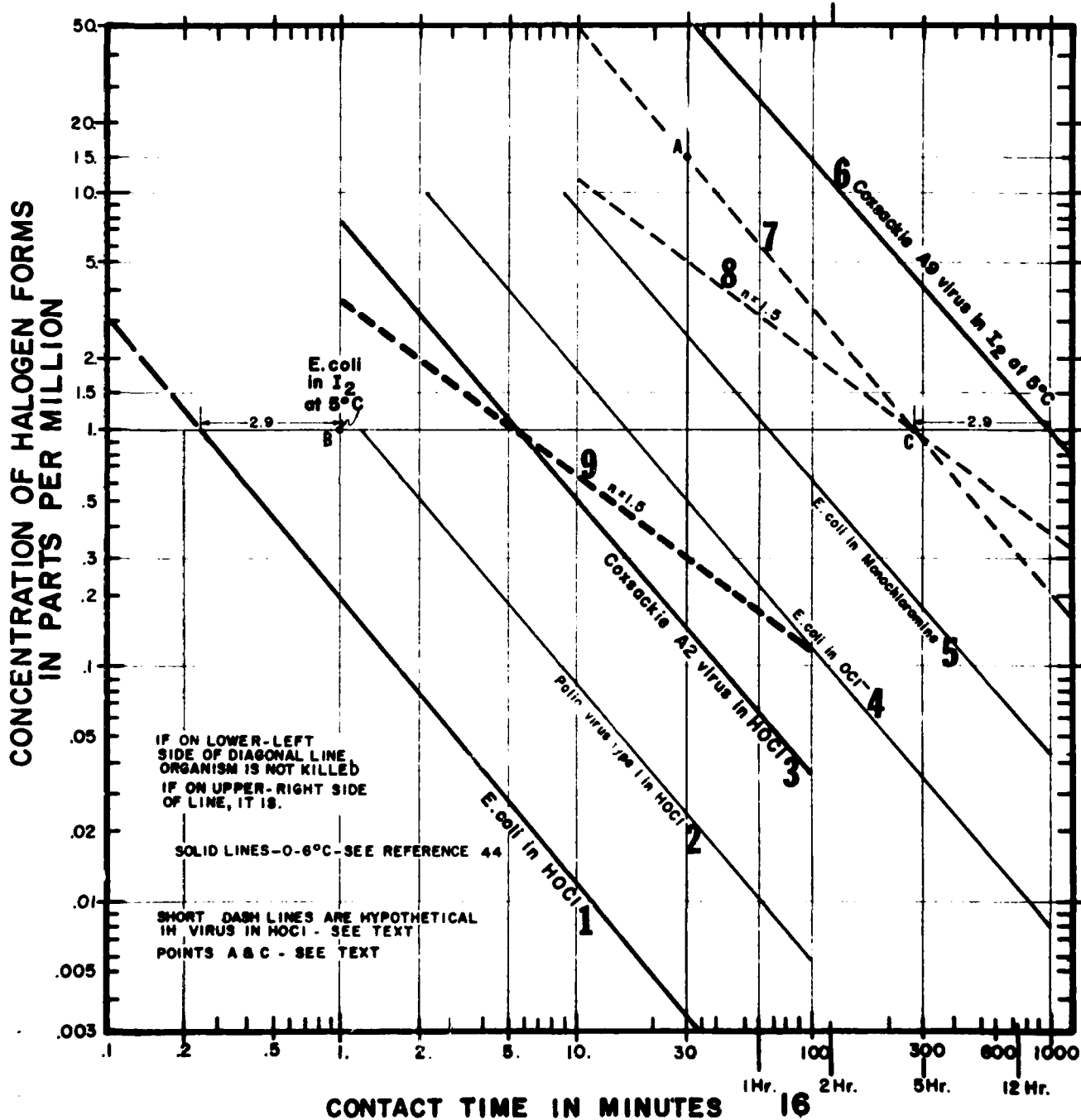
* Point C happens to be the value for Coxsackie A9 virus in I₂ at 15°C.

FIGURE 7

LOGARITHMIC PLOT OF CONTACT TIME (t) VS CONCENTRATION (C) for KILLING 99% of VARIOUS MICROORGANISMS WITH HALOGEN DISINFECTANTS

$$C^n t = K$$

n IS ASSUMED TO BE 1 UNLESS STATED OTHERWISE



HOCl would be required for 99% kill of IH virus. This happens to be at point A previously discussed. However, since the only n value we have for HOCl is 1.5 for *E. coli*, it seems slightly more logical to use this. At $n=1.5$ and 30 minutes contact time, 5 ppm HOCl would be required for 99% kill of IH virus under the several hypothetical assumptions made above.

b. The USAF in South Viet Nam (in response to a Dec 1966 MACV directive) chlorinates to 5.0 ppm free available chlorine after 30 minutes contact time at the point of treatment and also insists on 2.0 ppm at the point of consumption. This is true whether or not the water receives other treatment (coagulation, sedimentation, filtration, aeration)⁽¹⁴⁾. There has been no known instance of water borne hepatitis acquired from these supplies. IH admission rates have been in consonance with this. US Army representatives reported in 1967 that most Army IH cases showed strong correlation with the use of nonpotable ice.

c. Evidence indicates that IH virus is at least as resistant as Coxsackie A2 virus to HOCl. Coxsackie A2 is the most resistant virus for which we have HOCl data (line 3, Figure 7). In the absence of IH-in-HOCl data, if we assume IH is the same as Coxsackie A2, we require 0.3 ppm of HOCl for 30 minutes to kill 99% of IH virus if $n=1.5$ as it does for *E. coli* in HOCl (although line 1, Fig 7 is plotted as $n=1$). The 0.3 ppm is derived from Table 2 and interpolation on Figure 4, both of Appendix 1. This line has then been plotted as line 9 on Figure 7.

d. Hq TUSLOG recommended to all bases in Dec 1966 that 1.5 ppm free available chlorine residual be maintained in all TUSLOG water systems. This recommendation was followed to some extent. TUSLOG-1967-IH-admission rates were the lowest in 5 years both for USAF personnel (Figure 4, Page 5) and for dependents (Attachment 2). TUSLOG base waters in general have a top pH of 8. At pH 8, 1.5 ppm free available chlorine consists of 0.3 ppm HOCl at 28°C.

Pending further data, this practical argument (d) combined with (c) ~~seems~~ the most persuasive to arrive at an expedient conclusion. With argument (a) and the need for at least a slight safety factor in mind, it is therefore felt logical to require that all base water systems chlorinate to 0.4 ppm HOCl residual after 30 minutes contact time. If frequent pH testing cannot be done, but the pH has always been below 8, 1.5 ppm free available chlorine will satisfy this requirement.* If the source water shows evidence of human fecal contamination (which, with the present state of the art, must be taken to mean if it contains coliforms) maintenance of 0.6 ppm HOCl would be safer. We recommend these levels "at the treatment point" in accordance with NRC⁽⁶⁴⁾ rather than "in the active distribution system"^(40, 89).

Since free iodine efficiently inactivates some viruses at pH 7 or higher (if organic content is not high), much work is being done in an attempt to develop a more satisfactory procedure, possibly by using iodine and chlorine together. Until some procedure such as this is developed, reliance must be placed on chlorine at the levels discussed.

* In water at 10°C or below-Figure 2, Appendix 1 ($27\% \times 1.5 = 0.4$ ppm). The chlorinated water must remain at 10°C (50°F) or below during the 30 minute contact time i.e. in the storage tank.

VII TASTE/ACCEPTABILITY OF CHLORINATED WATER

The mouth taste organs distinguish only four "tastes". The general impression we call taste however is often a combination consisting largely of odor. Both taste and odor are subject to great individual variation and the relative contribution of pH, temperature and free available vs combined available chlorine is not known. The presence of other chemicals affects the taste impression greatly. One part per billion phenol can be detected when combined with chlorine ⁽¹⁵⁾. Chlorination of water to over .6 ppm will be resisted by some unknown percentage of people because of taste.

In 1956 in El Paso, Texas, "the free chlorine residual was increased from 0.75 to 2.0 ppm and the residuals in the far reaches of the distribution system were maintained at no less than 1.5 ppm. Almost all complaints from householders stopped. Experiments for a day or two with residuals of as high as 5.0 ppm in certain areas (of El Paso) did not lead to any unusual trouble. There are fewer complaints and these are now mostly from commercial establishments instead of from home owners. However some newcomers to the area notice a taste in the water-not usually unpleasant-and there are a few people with exceptionally sensitive palates. Many of the complaints are found to be the result of the action of chlorine with various foreign substances such as ... tastes in ice when insufficient coring has been practiced. El Paso's experience with 2 ppm chlorine residuals in the distribution system has, in general, been highly successful, especially from the standpoints of bacteriological safety, customer relations and economical treatment" ⁽⁶⁷⁾.

Balanced against this report is the report from a base in France that "virtually no water was consumed on the base by the French workers." The base water contained an average of 0.9 ppm total chlorine residual ⁽¹⁶⁾.

The percent of military personnel who will consume unauthorized water may increase:

- a. When new troops come to the area from a base without chlorination.
- b. When health education of troops is inadequate, ⁽⁸⁰⁾.
- c. As the free available chlorine increases beyond the taste detection threshold. This may be a straight line function for most people drinking one quality water. The threshold varies between persons and is heavily dependent on other chemicals in the water but is usually between 0.4 and 5.5 ppm.
- d. When personnel drink relatively tasteless iced drinks (e.g. ice water, vodka).
- e. As authorized water becomes more distant and difficult to obtain and conversely as unauthorized water becomes more available (e.g. field combat situation) and as thirst increases ⁽⁸⁰⁾.
- f. As enforcement of the consumption of only authorized water becomes more difficult. For troops living at home, enforcement is impossible.

There is a need for further data regarding all points, especially c and d.

IX SUMMARY-ABSTRACT

Military age personnel, who were reared on (a) water and food which were rigidly separated from human fecal contamination and/or (b) water and food which were extensively processed to remove or kill all pathogenic organisms, are susceptible to a long period of non-effectiveness due to hepatitis virus infection. In high incidence areas, this troop non-effectiveness can only be prevented by expensive mass gamma globulin administration, or by continuation of such separation and/or by continuation of such processing of "oral consumables", mass GG drains money and national stockpiles⁽⁸⁵⁾.

Complete processing of water may be expensive in some countries. In these countries, when military admission rates are high (i. e. above 1.5 per 1,000 per year), securing a bacteria free water source plus chlorination of the water to 0.4 ppm HOCl after 30 minutes contact time at the treatment site appears to be an inexpensive but usually adequate method for the temporary processing of water to prevent spreading of hepatitis by the water route. Frequent pH testing is often necessary in order to do this.

Close monitoring for purity of source water, absence of cross connections, performance of superchlorination after maintenance and absolute continuity of continuous water chlorination HOCl levels are essential. Water plant operator proficiency is essential for these⁽⁸⁰⁾.

When the ground-water source is bacteriologically contaminated, there is a very high probability of viral contamination. In a high-IH-incidence area, it must be assumed then, that the source water contains IH virus. Therefore chlorination to 0.6 ppm HOCl is recommended. However every practical effort should be made to secure a source that is always absolutely free of human fecal contamination and/or to provide other water treatment.

Providing a constantly-bacteria-free ground-water source requires at least sealed wells that are imperviously cased down far enough to provide adequate sand/soil 'filtration' from the ground surface. The extent of virus removal during passage through sand/soil depends in part on soil type⁽⁷⁶⁾ and on the flow rate through the soil. At higher flow rates, less virus is removed⁽⁷⁷⁻⁷⁹⁾. Below deep stream beds, flow rate may be high. When the static water level is close to the ground surface⁽⁷⁶⁾ and in fissured or fractured soil and rock⁽⁸⁶⁾, virus removal between the ground surface and the bottom of the impervious casing may be slight.

If coliform organisms are found in the distribution system, try to eradicate them by a trial of superchlorination. If not successful, at least 0.4 ppm HOCl must be maintained throughout the active distribution system. Otherwise, with the familiarity bred by prolonged operation, hepatitis outbreaks can be expected.

These chlorine levels are acceptable to most consumers for most purposes if phenols or other taste/odor threshold lowering agents are not present.

When a significant percentage of troops are likely to drink unauthorized water, measures should be taken to reduce this percentage.

As with poliomyelitis, if infants and children in referenced high-incidence areas are reared on oral consumables processed to kill all IH virus, when they reach military age many probably will be susceptible to clinical infection ⁽⁸¹⁾.

TÜRKÇE ÖZET

(a) Fekal Kontaminasyondan kat'ı surette tecrit edilmiş su ve gıda maddeleri ile beslenen ve/veya (b) içindeki patojenik organizmaların yok edilmesi için gerekli muameleye tabi tutulan su ve gıda maddeleri ile beslenen askerlik çağındaki personelin, uzun bir süre için hepatit virüs enfeksiyonlarına karşı mukavemetleri azalmış olur. Hastalığın insidansının yüksek olduğu bölgelerde askeri personelin bu direnç zayıflığı, büyük miktarda gamma globulin verilmesi veya su ve gıda maddeleri içindeki organizmaların evvelce olduğu gibi kontaminasyondan tecrit ve/veya yok edilmesine devam etmek suretiyle önlenabilir; Ayrıca herkese GG verilmesi ilaç stokunu da eritir ⁽⁸⁵⁾.

Bazı memleketlerde suyun temizleme muamelesine tabi tutulması pahalıya mal olabilir. Hastalık insidansının yüksek olduğu (senede 1000'den fazla) bu memleketlerde, içinde bakteri olmayan bir su kaynağı temin etmek ve muameleye tabi tutulduktan 30 dakika sonra 0.4 ppm HOCl evsafılı içme suyu temin etmek viral hepatitin su yolu ile yayılmasını önlemek amacıyla suyun muvakkaten temizlenmesi bakımından ucuz ve yeterli bir metod olarak kabul edilebilir. Bunu yapabilmek için suyun sık sık pH testi yapılması gereklidir.

Suyun menbaında temizliğin devamlı kontrolü, su çebekesine dışardan sızıntı olmasının önlenmesi, klorlamanın tam olarak yapılması ve suda HOCl seviyesinin kat'ı ve devamlı olarak idamesi şarttır. Bu maksatla suyu kontrol eden şahsın işinin ehli olması gerekmektedir.

Su menbaında bakteriyolojik bir kontaminasyon varsa viral kontaminasyon ihtimali de yüksektir. İnfeksiyöz Hepatit insidansının yüksek olduğu bir bölgede su menbaının IH virüsü ihtiva edebileceği ihtimali nazarı itibara alınmalıdır. Bu sebepten klorlamanın 0.6 ppm HOCl derecesinde yapılması tavsiye olunur. Maamafih insan fekal kontaminasyonundan tamamen arı bir su menbai bulmak ve/veya suyun temizleme muamelesine tabi tutulmasını temin etmek için gerekli her türlü gayret sarfedilmelidir.

Devamlı olarak bakteriden arı bir yaraltı su menbai temin etmek için yeterli kum/toprak filtrasyonu olması bakımından toprak seviyesinden kafi derinliğe kadar inen etrafı su geçirmez şekilde inşa edilmiş ve üstü tamamen kapalı su kuyuları olması lazımdır. Virüslerin kum/toprak filtrasyonu esnasında giderilme derecesi kısmen toprağın cinsine ⁽⁷⁶⁾ ve suyun akış derecesine bağlıdır. Hızlı akış derecelerinde virüs giderilmesi daha azdır ⁽⁷⁷⁻⁷⁹⁾. Derin su yataklarının altında akış hızı yüksek olabilir. Statik su seviyesi toprak seviyesine yakın olursa ⁽⁷⁶⁾ ve arazi çatlak yahut kırık kaya veya toprak ise toprak seviyesiyle kuyunun su sızdırması kısmının dibi arasındaki bölgede virüs izalesi pek cüz'ı olur.

Tevzi sisteminde koliform organizmaları bulunursa super klorlama suretiyle bunların giderilmesine çalışılmalıdır. Bunda muvaffak olunmаса, tevzi sisteminde devamlı olarak en az 0.4 ppm HOCl bulundurulması lazımdır. Aksi takdirde, uzun müddet alınsadan mütevellit, hepatit salgınları zuhur etmesi muhtemeldir.

Şayet suda phenol ve benzeri diğer lezzet bozan veya koku yapan maddeler yoksa, bu klor dereceleri suyu kullanan şahıslara birçok bakımlardan uygundur.

Mühim miktarda askeri personelin içilmesi yasak olan bir suyu içmesi ihtimali varsa bu miktarın asgariye indirilmesi için gerekli tedbirler alınmalıdır.

Poliomyelitis hususuna gelince.. bebekler ve küçük yaştaki çocuklar yukarıda belirtilen yüksek insidanslı bölgelerde IH virüsünün yok edilmesi gayesiyle gerekli mameleyle tabi tutulan su ve gıda maddeleri ile beslendikleri takdirde, bunlar askerlik çağına geldikleri zaman klinik enfeksiyona karşı muhtemelen hassas olurlar.

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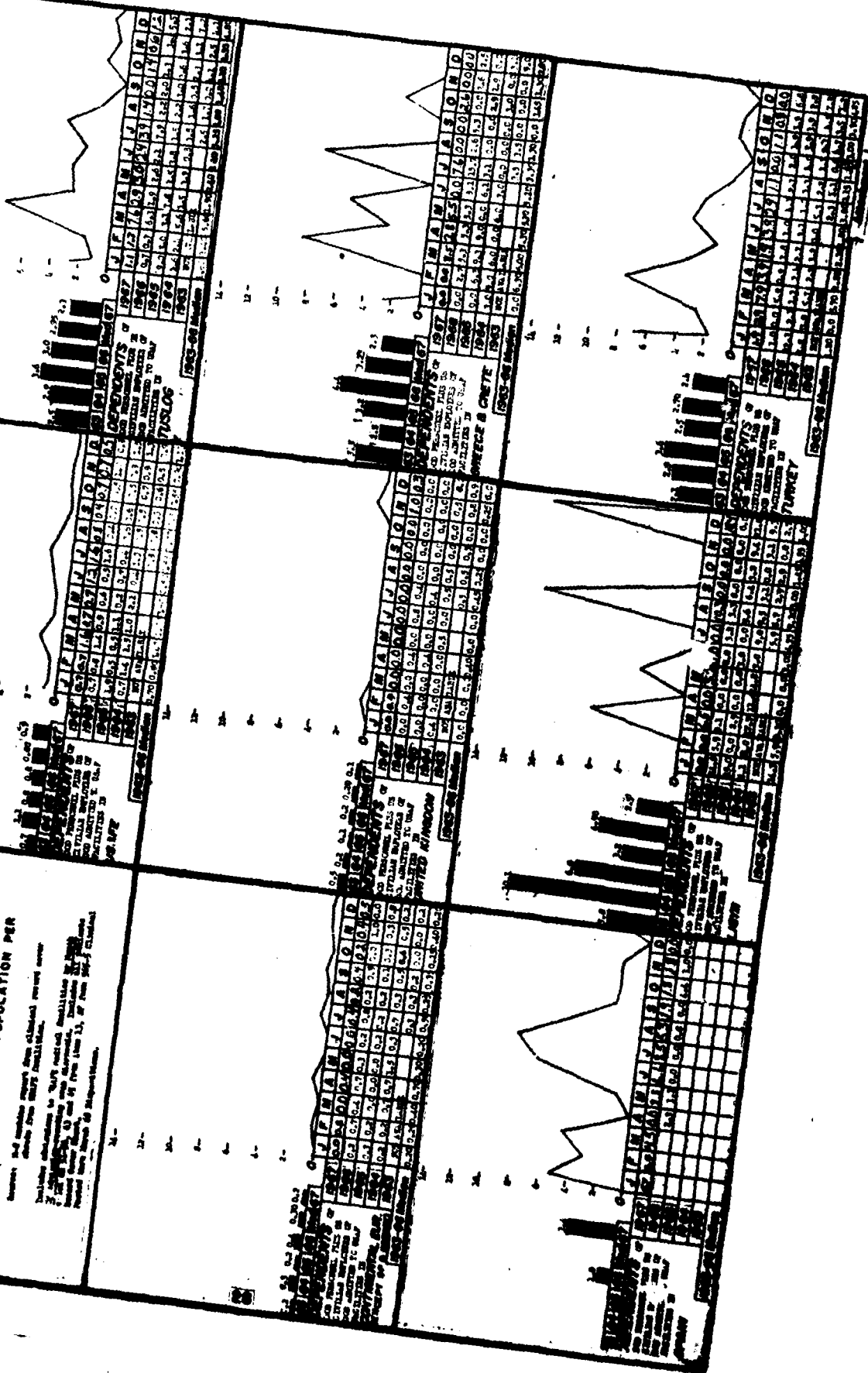
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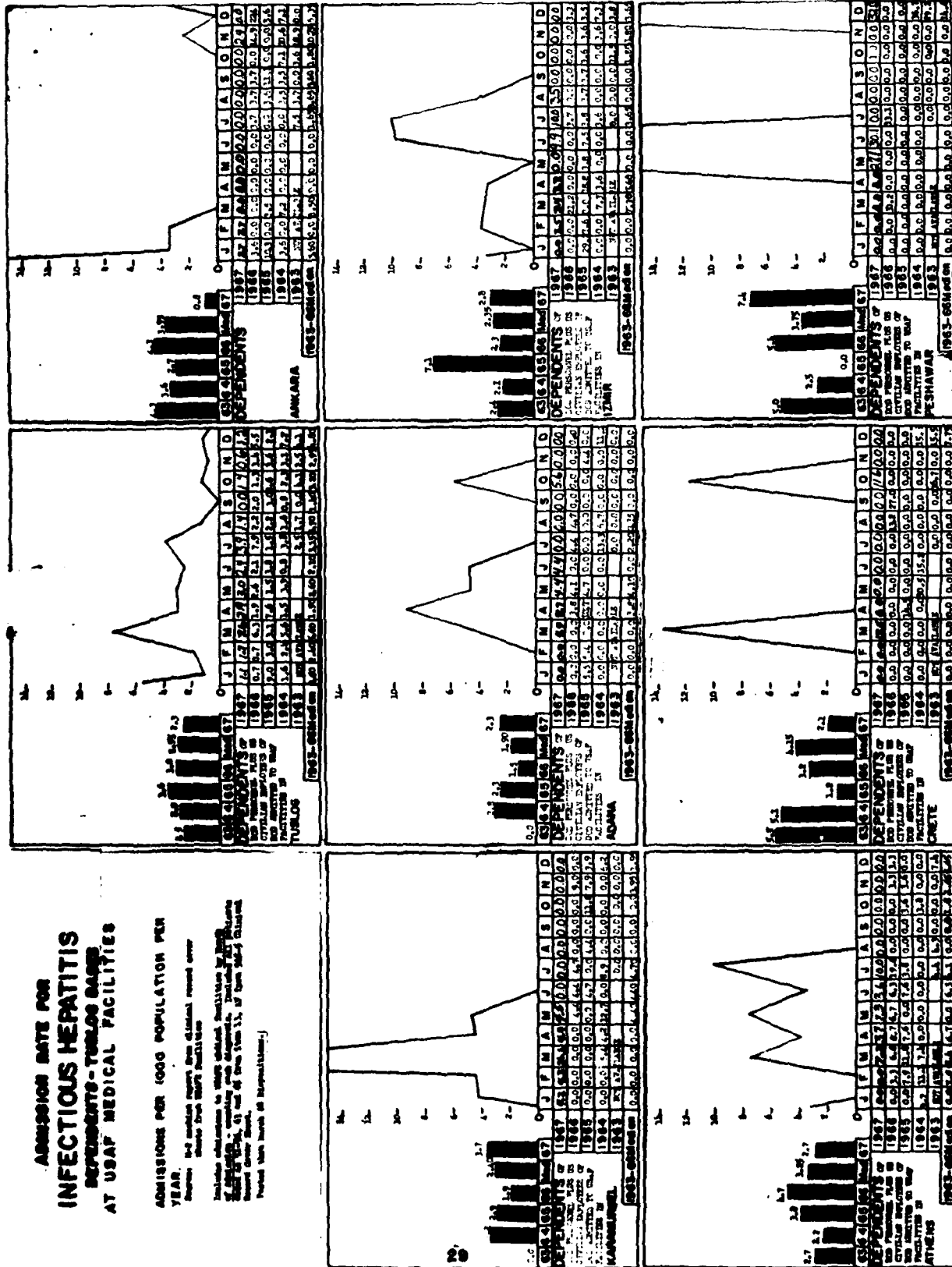
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Includes admission to three school sessions by day of students - evening not included. Includes all picture films at \$1.00, 45 out of two film 1.5, 15 two film 4.00 and second dinner break.

Period from March 28 to September 1.



United States and Foreign Water-Borne Outbreaks of Infectious Hepatitis from Surface Water Supplies,* 1895-1963

Date	Location	No. Cases	Type of Supply	Treatment	Most Likely Reason	Source
1895†	Kings Lynn, England	34	Public	None	Village using polluted stream.	?
1944†	Pennsylvania (summer camp)	255	Private	None	Contaminated wells.	Wells
Feb. 1948	Rural Pennsylvania	9	Private	None	Probably seepage of sewage from adjacent cesspool (retrospective study).	Well
July 1949	Willamette, Ore. (restaurant)	6	Private	Chlorination	Probably inadequate chlorination.	Well
Sept. 1949	Las Cruces, N. M.	25	Public	?	Back siphonage.	Wells
Oct. 1949	Glide, Ore. (school)	125	Private	Chlorination	Interruption of chlorination. Well water also cross-connected to raw river water.	Well
Aug. 1950	Lane Co., Ore.	8	Private	None	Use of polluted water not intended for drinking.	Spring
July 1952	Tennessee (church camp)	104	Private	None	Seepage of sewage dye traced from leak in sewer line.	Spring
Dec. 1952	Vashon Island, Wash.	100	Public	?	Incomplete information on file, possibly due to water.	?
March 1953	Sterling, Colo. (school)	49	Public	?	Possible cross connection with toilet.	?
Dec. 1953	Mercersburg, Pa. (school)	25	Private	None	Use of polluted ground water. Privies on hill above spring.	Spring
1953	California (industrial housing area)	32	Public	?	Back siphonage from clothes washers	?
Dec. 1955	Delhi, India	28,745	Public	Filtration and disinfection	Low and combined chlorine at Chandrawal plant ^a	Surface
1955	Yuba Co., Calif. (Comptonville picnic area)	9	Private	None	Fecal contamination of water used. Water used to make fruit punch.	Stream
1955	Kotzebue, Alaska	21	Private	None	Contamination of watershed by feces.	Ponds
March 1956	Curwensville, Pa.	170	Public	Chlorination	Unapproved sources and low chlorine residual.	Stream and spring
June 1956	Utica, Ky.	9	Private	None	Seepage of sewage from septic tank, proven by dye studies, into adjacent wells.	Wells
Nov. 1956	Rhinebeck, Rhinecliff, N. Y.	83	Public	Chlorination	Inadequate chlorination.	Surface and well
1956	Arkansas (school)	?	Public	?	Use of polluted water on football field.	?
Jan. 1959	Posen, Mich.	164	Private	None	Underground pollution of wells through creviced limestone.	Wells
Dec. 1959	Hawkins Co., Tenn. (small subdivision)	10	Public. Privately owned not approved	?	Probably seepage of sewage.	Well
May 1960	Craigsville, W. Va. (school)	?	Private	None	Overflow of sewage after dishwasher hooked into line.	Wells
June 1960	Brookfield, Conn. (school)	22	Private	?	Seepage of sewage.	Well
Sept. 1960	New York	21	Private	Chlorination	Inadequate chlorination only treatment (retrospective study).	Lake
April 1963	Artesia, Colo.	14	Public	None	Cross connection with toilet in a school.	Wells
		Total: 30,040				

* All except † items taken from tables supporting: Wolfel, S. R.; Dixon, F. R.; Weidner, R. B.; and McCabe, L. J. Waterborne Disease Outbreaks, 1946-1960. J. Am. Water Works A. 54:9, 947-950 (Aug.), 1964.
 † See Reference 4.
 ‡ Report of Colorado Department of Public Health.

DEPARTMENT OF THE AIR FORCE
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APO New York 09224

EPIDEMIOLOGY

INFECTIOUS HEPATITIS AND WATER:
EVALUATION AND CHLORINATION

APPENDIX I

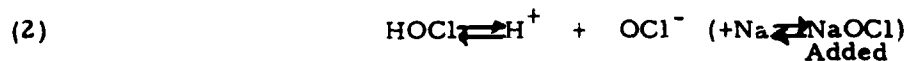
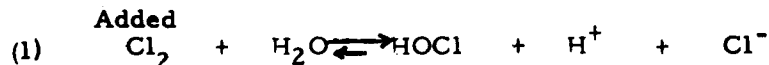
DISINFECTION BY CHLORINE-CHEMISTRY-TERMS-EQUATIONS

1. An understanding of the definition of terms and of the reactions of chlorine in polluted water is essential to predict the success of chlorination. Chlorine dosage is the term used to indicate the amount of chlorine added to water. It is often expressed in terms of the calculated total theoretical chlorine concentration (e.g. ppm = mgm/liter) that addition of a given amount of chlorine would give (if the added chlorine underwent no chemical combination). When chlorine gas (Cl_2) is added to water, chlorine remains in the water as molecular chlorine (Cl_2) for only a very short time. It then combines with other chemicals as in a, b, c and d below:

a. The combination of chlorine and water to form free available chlorine. Free available chlorine is the name commonly applied to a group of 3 forms of chlorine which may be found in water. These are molecular chlorine (Cl_2), hypochlorous acid (HOCl), and hypochlorite ion (OCl^-).

When sodium hypochlorite or calcium hypochlorite are used instead of chlorine gas, the hypochlorites ionize immediately to hypochlorite ions and calcium or sodium ions⁽⁶⁸⁾. The hypochlorite ion associates with a free hydrogen ion in the water and distributes itself between HOCl and OCl^- . Thus the end result is the same as when chlorine gas is used except for the presence of Na or Ca.

The following equations show the development of these chlorine compounds in water:

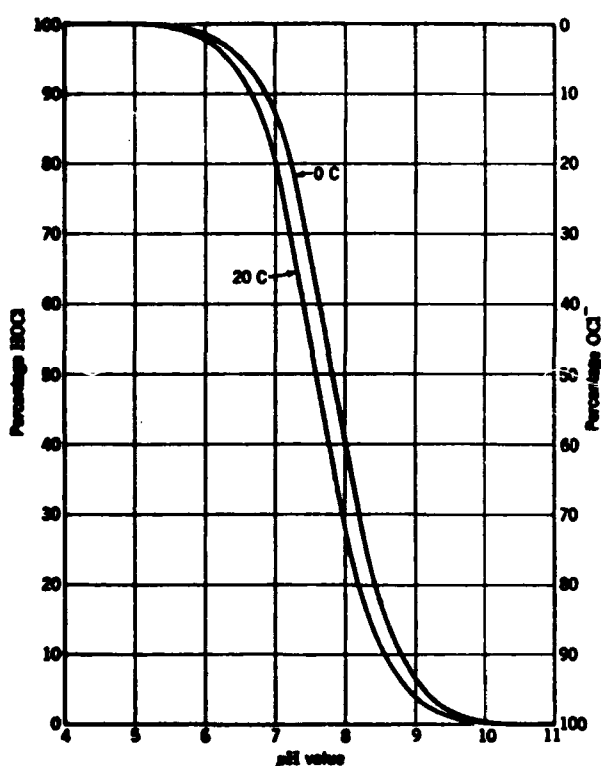


Since reaction (1) proceeds almost entirely to the right when pH is above 3 and total chlorine is less than 1000 ppm⁽⁶⁹⁾ and the chloride ion (Cl^-) is not a disinfectant, the free available (disinfectant) chlorine concentration $\approx [\text{HOCl}] + [\text{OCl}^-]$ (i.e. $[\text{Cl}_2]$ is ignored).^(69, 87) These compounds are formed initially and remain if there are no nitrogenous compounds present in the water. If nitrogenous compounds are present

* Square brackets (historically utilized to denote the concentration in gram molecules per liter of the substance whose formula is between them) are herein used to denote concentration in ppm.

and more than sufficient chlorine is added to supply all the chlorine that the nitrogenous and other compounds will take up (see 2 below), free available chlorine compounds will be present. Of these 3 forms of free chlorine, only HOCl efficiently destroys micro-organisms. OCl^- has only about 1/80th the bactericidal efficiency of HOCl (*E. coli* 30 min at 2-5°C) (69) and can be assumed to have no virucidal effect. (70). The bactericidal efficiency of free available chlorine is determined by the pH of the solution, the contact time and the temperature. The pH of the solution determines the relative amounts of the chlorine which will be in the forms of HOCl and OCl^- (i.e. how far equation 2 proceeds). Figure 1 shows the percent concentration of free available chlorine as HOCl and OCl^- as a function of pH from pH 4 to 11 at temperatures 0° and 20°C.

FIGURE 1 (69)



Distribution of hypochlorous acid and hypochlorite ion in water at different pH values and temperatures.

Obviously the critical portion of this curve is in the pH range of 6.5 to 8.5 which is also the range in which most water supplies fall. Figure 2 is an enlargement of the critical portion of the Figure 1 curve. Table 1 is the actual data used to plot Figure 2. Therefore for field calculation either Table 1 or Figure 2 should be used in order to obtain more accurate values than available from Figure 1.

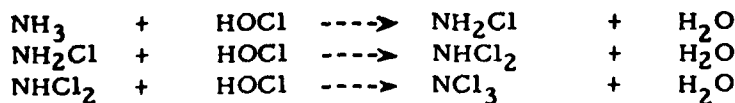
On Table 1 to obtain ppm HOCl, multiply the percent found by the ppm free residual chlorine at any specific temperature and pH.

b. The combination of chlorine with inorganic reducing substances. Frequently encountered reducing substances are ferrous iron, manganous manganese, nitrites and hydrogen sulfide. These react with chlorine much more rapidly than organic substances react with chlorine. The chlorine going into these reactions loses its bactericidal action completely. Enough chlorine must be supplied to complete these reactions before disinfection can be accomplished.

c. The combination of chlorine with ammonia and amines. Ammonia and amines are frequently present in natural waters and react readily with hypochlorous acid to form monochloramine (NH_2Cl), dichloramine (NHCl_2), or nitrogen trichloride (NCl_3). This is probably a step reaction as represented by the following equations:

TABLE 1

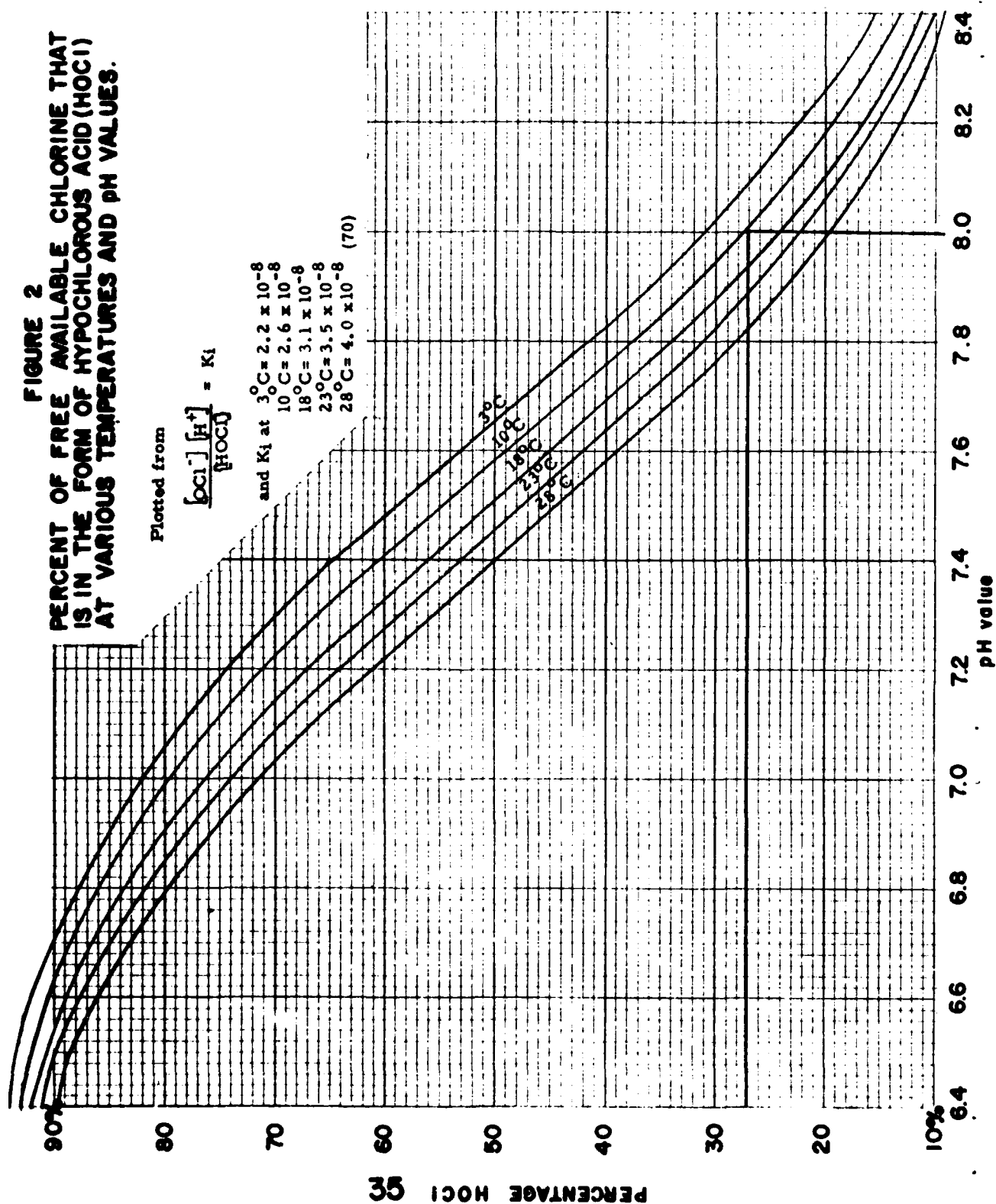
Percent of Free Residual Chlorine that is HOCl					
When pH is:	When Temperature is:				
	3°C	10°C	18°C	23°C	28°C
6.4	94	93	92	91	89.5
6.5	93.5	92.3	91	90	88.6
6.6	92	90.5	89	87.6	86
6.7	90	88.5	86.5	85	83
6.8	87.6	86	83.5	81.6	79.6
6.9	85	83	80.3	78.3	75.8
7.0	82	79.6	76.2	74	71.5
7.1	78.3	75.8	72	69.3	66.5
7.2	74.2	71	67	64.1	61
7.3	70	66.1	61.6	58.8	55.5
7.4	64.5	60.5	56	53	50
7.5	59	54.8	50.5	47.4	44.2
7.6	53	49	45	42	39
7.7	47.5	43.5	39.5	36.4	33.3
7.8	41.9	37.8	34	31.2	28.2
7.9	36	35.2	29	26.5	23.9
8.0	31.2	27.5	24.1	22.2	19.9
8.1	26.5	23.2	20.1	18.5	16.1
8.2	22.5	19.5	16.7	15.3	13.2
8.3	18.5	16	13.9	12.5	11
8.4	15.4	13.3	11.4	10.2	9.1
8.5	11.2	10.8	9.25	8.25	7.35



The NCl_3 is not formed in significant amounts within the normal pH range except with HOCl concentrations above breakpoint dose (69). (See page 37). The disinfecting action of chlorine is greatly modified by its change to chloramine. In this form the chlorine continues to destroy bacteria but has much less effect on viruses. The principal factors affecting the bactericidal effectiveness of the chloramines are (1) the pH of the solution, (2) the temperature of the solution, and (3) the concentration of chloramines.

With an increase in pH, there is a decrease in the bactericidal action of the solution. This is explained on the basis of the relative amounts of dichloramine and monochloramine in the solution. Dichloramine (formed at lower pH values) is a more effective disinfectant. Also, the presence of an excess of ammonia affects the formation of the desirable dichloramine. With a chlorine to ammonia weight ratio of 5:1 the following may be expected:

FIGURE 2
PERCENT OF FREE AVAILABLE CHLORINE THAT
IS IN THE FORM OF HYPOCHLOROUS ACID (HOCl)
AT VARIOUS TEMPERATURES AND pH VALUES.



pH	Percent of chlorine as dichloramine
5	84
6	62
7	35
8	15
9	6

Regarding temperature effect, a general rule is that a reduction of 20°C. (from about 23°C. to about 3°C.) necessitates 9 times as long a period of contact or 2.5 times as much chloramine to produce a complete kill of bacteria.

Chloramines are much less efficient bactericidally than HOCl. About 25 times as much chloramine as free chlorine is required under similar conditions and 100 times as long a contact period is required for chloramine if the same amount of each is used. In a water of a high pH, chloramines will produce very little bactericidal action at low temperatures.

More complex natural chloramines occur but these have even less disinfectivity. A synthetic complex chloramine of interest is Halazone $\text{HOOC} \diamond \text{SO}_2 \text{NCl}_2$ which is prepared as a 4 mgm tablet, formerly used in a 1 liter canteen to sterilize the water. It acts principally by slowly releasing HOCl.

d. The combination of chlorine with organic substances other than amines. All natural surface waters and some ground waters contain organic matter. Chlorine reacts with oxidizable organic material including microorganisms. Many of the initial reaction products have objectionable odors. When sufficient chlorine is present the reactions go through to completion and form stable compounds which usually do not contribute to tastes and odors. The amount of chlorine necessary to complete these reactions is in direct proportion to the amount of organic material present in the water. Large amounts of organic matter in water discolor water. Therefore, water with greater amounts of color will usually require more chlorine. Because the chlorine consumed by these reactions is completely lost insofar as its further bactericidal action is concerned, sufficient chlorine must be added to water to stabilize the organic material and leave a residual to meet the other demands.

Total chlorine residual, chlorine residual, residual chlorine or total available chlorine, formally called "free chlorine" concentration is the concentration of free available chlorine plus the concentration of chloramines, plus the concentration of a minor amount of the other above reaction products (e.g. sulfur/sulfide compounds ¹⁵). There are thousands of chlorine compounds, each with different dissociation constants. Many may be present in chlorinated water but the above 4 groups generally characterize them all. Total chlorine residual is the chlorine which can still take part in chemical reactions, i.e., that chlorine which is not fixed by a firm chemical bond (e.g. with organic material). Practically, under present field conditions, the total chlorine residual is the chlorine which is in a state to react within 5 minutes with orthotolidine to produce a yellow color. (See para 2a)

$$\left[\begin{array}{c} \text{Total chlorine} \\ \text{residual} \end{array} \right] = \left[\begin{array}{c} \text{Free available chlorine} \end{array} \right] + \left[\begin{array}{c} \text{Combined available residual} \\ \text{chlorine} \end{array} \right]$$

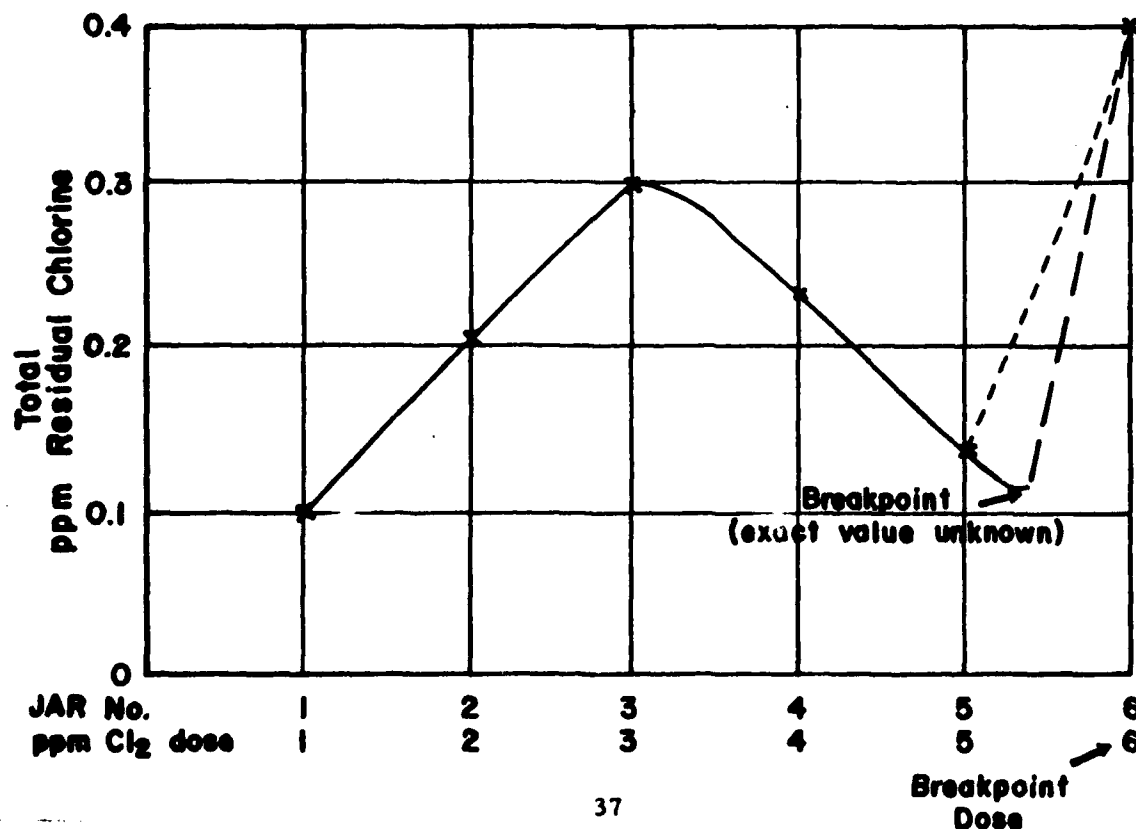
Since the combined available residual chlorine is usually in the form of NH_2Cl and NHCl_2 , some authors define combined available residual chlorine as the sum of only these two (68).

$$\left[\begin{array}{c} \text{Chlorine demand} \end{array} \right] = \left[\begin{array}{c} \text{Chlorine dose} \end{array} \right] - \left[\begin{array}{c} \text{Total chlorine residual} \end{array} \right] \quad (49) \text{ thus,}$$

$$\left[\begin{array}{c} \text{Chlorine dose} \end{array} \right] = \left[\begin{array}{c} \text{Combined nonavailable} \\ \text{chlorine} \end{array} \right] + \left[\begin{array}{c} \text{Combined available} \\ \text{chlorine} \end{array} \right] + \left[\begin{array}{c} \text{Free available} \\ \text{chlorine} \end{array} \right]$$

2. BREAKPOINT CHLORINATION. Much of the above confusing terminology has developed due to the former inability to measure (or lack of realization of the importance of) the bactericidal free available chlorine and its two components. Total chlorine residual could be measured, however, and the following could be performed: Fill ten 500cc jars with water, then add one drop of 1% chlorine solution to jar no. 1 (dose=1.0 ppm), two to jar no. 2 etc.. Stir and allow to stand 30 minutes. Test all jars for total chlorine residual (See 3a below). In general, the total chlorine residual is higher in the higher numbered jars. However, one or several consecutive jars will show a lower total chlorine residual than the lower numbered jars. The "breakpoint" dose is the ppm chlorine originally added to the lowest number jar beyond this fall. This is the first jar with a free available chlorine content.

FIGURE 3 TYPICAL CURVE FORMED BY PLOT OF OBSERVATIONS FROM BREAKPOINT TEST ON FAIRLY "POLLUTED" WATER



Breakpoint chlorination of water supplies requires the addition of a sufficient quantity of chlorine to meet all the demands of the water (stabilize organic and inorganic substances) and still leave a residual of free available chlorine. Breakpoint chlorination controls both the amount of the total residual chlorine and more important, the nature or form of that chlorine. The older processes of adjusting dosage to achieve a certain total residual chlorine concentration controlled only the amount of the total residual chlorine.

Compared to the older method of chlorination only to a certain total residual chlorine, the advantages of chlorinating to the breakpoint dose to assure the presence of free available chlorine are: (1) a quick and reliable killing of bacteria; (2) reduction in tastes and odors resulting from organic materials present in the water; (3) bleaching of color in the water; and (4) prevention of biologic growths in the filter plant and distribution system. Chlorine consumption will of course be higher. Some water may require less than 1 ppm chlorine dose to produce free available chlorine; other water may require from 15 to over 100 ppm.

3. TESTING FOR RESIDUAL CHLORINE

a. The standard orthotolidine test (OT), for total chlorine residual is made by adding an acid orthotolidine dihydrochloride solution to water, waiting 5 minutes and comparing the developed color with standards of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.8, 1.0 and 1.5 ppm. The accuracy may be affected by the presence of certain interfering oxidizing agents. The effect of these interfering substances is to develop additional color above that resulting from the chlorine.

b. The orthotolidine flash test may be used to obtain a qualitative determination of the presence of free available chlorine. Free available chlorine reacts almost instantly with orthotolidine, but chloramines react relatively slowly. This difference is especially noticeable at temperatures below 60°F. The reading obtained about 5 seconds after the addition of orthotolidine will approximate the amount of free available chlorine in the water and the reading taken after 5 minutes will give the total residual chlorine in the water. The difference between these readings will be the amount of combined available residual chlorine in the water.

c. The orthotolidine-arsenite test (OTA) is really three tests; (1) a standard OT test, (2) an OT flash test but modified by the addition of sodium arsenite to stop the reaction after 5 seconds, and (3) a test for interfering ions. The OTA test thus measures the concentration of free available chlorine and combined available chlorine; it also corrects some of the false color reactions due to interfering substances in the water. It is at present the only fully tried accurate and dependable field test and is the test of choice if free available chlorine is to be measured, or if it is suspected that interfering substances are present. A modification of this test, described by CDC, (88) consists of deleting the first (OT) part of the test.

d. The above described field tests sometimes do not give completely accurate quantitative results in the presence of large amounts of interfering substances or at high temperature. For example, the OTA test gives low readings for total chlorine residual

but, with chlorine dosages below the breakpoint, the OTA test may indicate up to 0.2 ppm free chlorine residual when actually none is present (83). Interference may occur from organic color and nitrite oxidants other than chlorine, notably iron (III) and manganese (III) and (IV). Recently new field procedures have been studied and an attempt has been made to develop better techniques to obtain free available chlorine concentrations in water. Some of these procedures utilize methyl orange (83), diethyl-p-phenylene diamine (84), and an anionic surface active stabilizer added to neutral orthotolidine. Until further evidence is released, the OTA test can usually be relied on in the European/Middle East Area.

4. TESTING FOR pH. The test for pH is usually performed in the field by adding bromthymol blue (which measures pH over a range of 6.0 to 7.6) or phenol red (which measures pH over a range of 6.8 to 8.4) to water, shaking gently to obtain even mixing and a uniform color, and then comparing the developed color with standards of pH 6.0, 6.2, 6.4, 6.6, 6.8, 7.0, 7.2, 7.4, 7.6, 7.8, 8.0, 8.2, and 8.4.

5. THE ACTION OF CHLORINE ON BACTERIAL CELLS. It is reasoned that because chlorine is effective at high dilution, it must inhibit some key enzymatic process within the cell. Iodine seems to act on some other essential enzyme which may explain its greater cysticidal power. When enzymes are removed from cells, the cells are susceptible to destruction by a number of other oxidizing agents, including hydrogen peroxide and potassium permanganate, which are known to be inferior disinfectants. This indicates that the cell walls are important in preventing entrance of these disinfectants into the cells. The rate of action of these agents is in direct proportion to their rate of penetration through cell walls. HOCl is a superior disinfectant, not merely because of its strong oxidizing power, but because its small molecular size and neutral electrical charge enable it to penetrate cell walls quickly.

6. CONTACT TIME AND CONCENTRATION

The rate at which microorganisms in water are killed by chlorine depends on the chemical form of chlorine present, the pH and the temperature as we have seen, and also on:

- a. The length of contact time. When all other factors are held constant this may or not be a straight line function (68). It will be assumed to be straight line here.
- b. Concentration of disinfectant. In all cases, the greater the concentration the more quickly organisms are killed but, "how much more quickly," varies.

The contact time needed to kill any one percentage of any one species of microorganism for any one form (or set combination of forms) of disinfectant at constant pH and temperature can be expressed by an empirical equation:

$$(\text{Concentration of disinfectant})^n (\text{Time required to kill certain \%}) = K$$

$$c^n t = K$$

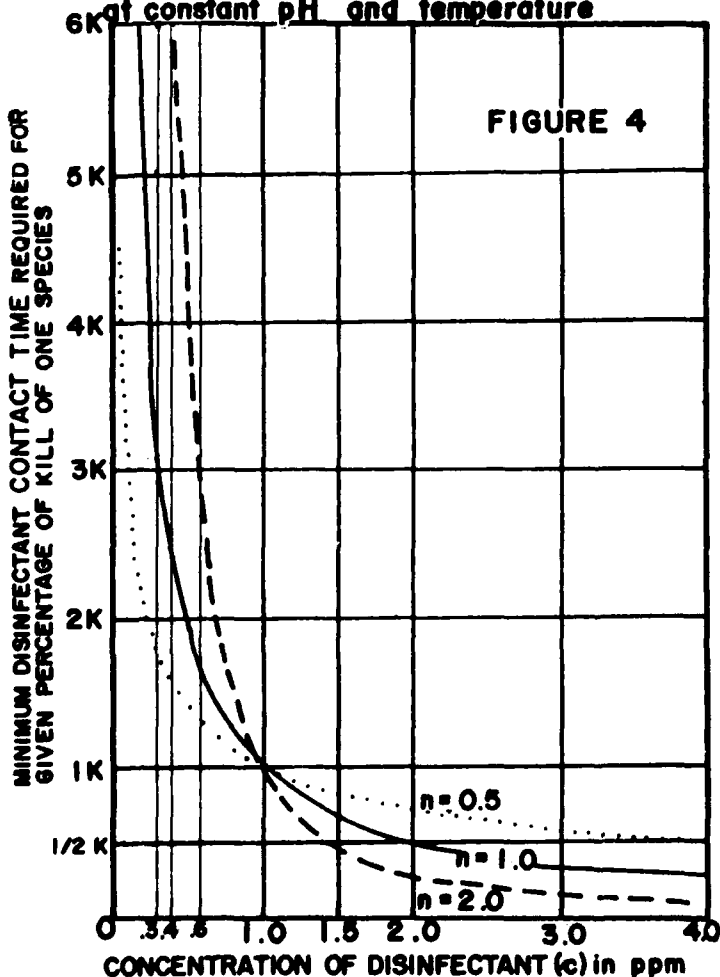
where K is a constant for all times and concentrations, and the exponent n is called the coefficient of dilution. It varies around one, and when unknown, may be assumed to be approximately one. Figure 4 is a plot of positive values of this equation for 3 values of n. Each curve approaches the two axes asymptotically. The curve n=1 is a rectangular equilateral hyperbola.

The value of K for use on the Figure 4 graph is given as follows:

TABLE 2 (69)				K	10/K	n
99% Kill of	in	at pH	and temperature in degrees C	is achieved by 1 ppm in	killing power	equals
1. E. coli	HOCl	7.0	2-5	0.2 min	50.	1.5
2. E. coli	I ₂	?	0-6	1.0 min	10.	?
3. Coxsackie A2	HOCl	-	0-6	5.0 min	2.	?
4. E. coli	OCl ⁻	10.0	2-5	16.5 min	0.6	0.8
5. E. coli	NH ₂ Cl	high	0-6	60.0 min	0.17	?*
6. Coxsackie A9	I ₂	?	15	5.0 hrs	0.034	?
7. Coxsackie A9	I ₂	?	5	20.0 hrs	-	?

* Chloramines at pH 7-9.5, 2-5°C here n=1.3

**CONTACT TIME (t) VS CONCENTRATION (c)
for KILLING MICROORGANISMS with
DISINFECTANT $C^n t = K$
at constant pH and temperature**



Any increase in concentration (c), decreases the time needed to kill. The rate of decrease, however, is different for different conditions (e.g. different disinfectants). n expresses the variance.

The reciprocal of the constant, K, can be thought of as the killing power for the given set of circumstances. For ease 10/K is used in Table 2. If we have a 1.5 ppm free residual chlorine solution at 28°C and pH 8.0 (i.e. 20% HOCl and 80% OCl⁻ from Figure 2), the total killing power might be expressed as:

$$50(.2 \times 1.5) + 0.6 (.8 \times 1.5) \\ 15 + 0.7 = 15.7$$

The killing power provided by the 1.3 ppm OCl⁻ is seen to be negligible (i.e. 0.7). Monochloramine is even less help. In Figure 4 we see that if n=1.5, the 0.3 ppm HOCl alone would take about 1 minute to kill 99% of the E. coli.

The curves in Figure 4, plot as a straight line on logarithmic graph paper; the slope of the line being -1/n.

7. MICROORGANISM LOAD

The equation $c^n t = K$, deals with a projection into future time from an instantaneous moment of measurement. Its prediction of time-of-99%-kill, for example, is true only if c does not change during this time. If no disinfectant is added, c will decrease during the killing time. The killing process binds chlorine and thus removes it from the free residual concentration.

Even in a solution of only free available chlorine and organisms, the rate and extent of free available chlorine decrease depends on how many organisms there are to be killed. This means that when trying to cut chlorine costs and increase taste acceptability by using the minimum safe amount of chlorine one must:

- (1) calculate the minimum values for c and t that will perform the killing job one wants.

- (2) maintain at least that minimum value of c until time (t) has transpired or until the water stabilizes and no further decrease in c is experienced, whichever is longer. This is essential even though the concentration remaining after stabilization and time (t) is in a sense wasted. There is nothing more for it to kill. It does provide some protection against maldesign and mismanagement (e.g. cross-connections or other sources of chlorine demand in the system).

APPENDIX II

RESPONSIBILITIES OF THE USAF MEDICAL SERVICE IN WATER SUPPLY SANITATION (See also reference 89)

The USAF Medical Service is charged with the responsibility of exercising sanitary supervision over water supplies from source to consumer and making such recommendations as may be necessary to protect the health of troops. Many Military Public Health (MPH) sections feel this responsibility is fulfilled by performing routine bacteriological analyses and free available chlorine residuals of the chlorinated water in the distribution system. All of the following should be objectives especially where infectious hepatitis rates are high and chlorination is the only method of treatment.

1. "Routine inspection of the entire water supply system from a sanitary point of view". * The water source, treatment, storage and distribution system of the base should be studied. This includes knowing the location of all water sources and the surrounding environment. By knowing this, potential sources of contamination may be identified. If ground water is used as the water source, the soil strata should be known since, for example, strata such as limestone with fissures may carry contaminated waters to the water source. Construction of wells should be studied for any sanitary discrepancies that may exist. When water is chlorinated, storage and contact time are important. Calculate the actual minimum contact time (Appendix III). All water distribution lines should be studied to eliminate cross-connections that may exist, since this is an obvious and proven source of contamination. Do actual on-site operators understand chlorination requirements and significance of any cross-connections? Review operator records. Is adequate superchlorination always performed when required?

2. "Recommendations to the individuals or services concerned regarding the correction of sanitary defects or health hazards that may be found". Close liaison with Civil Engineering and civilian contractor personnel should be maintained. Bactericidal and virucidal effects of chlorine in water should be explained to them and the importance of constant and reliable chlorination emphasized. Military Public Health sections and Civil Engineering personnel should work together in eliminating cross-connections. Initial construction plans of wells, pump houses and distribution lines should be reviewed by the MPH section before construction. MPH personnel should emphasize the need for superchlorination of water in mains, wells, storage tanks and other units since these units may become contaminated during construction and repair.

3. "Collection of water samples". A minimum of eight samples per month should be taken from the distribution system for bacteriological analysis regardless of the population strength of the installation, or one sample per 1,000 persons

* All quotes are from Air Force Manual 160-4, Sanitary Control of Water Supplies for Fixed Installations dated 17 December 1957 (40).

per month on all military installations with strengths in excess of 8,000. A diagram of the distribution system should be on hand as a guide in determining sampling points. Additional water samples for bacteriological analysis should be taken from the raw water sources, water lines to the treatment plant and storage tanks to gain additional information and assist in the interpretation of results.

4. "Interpretation of the results of analysis of the water samples". References AFM 160-4 and USPHS Drinking Water Standards (40,54) should be used to interpret physical, chemical and bacteriological test results of water samples.

5. "Conduct routine chlorine residual tests". When monthly bacteriological samples are collected, free available chlorine residual and pH and water temperature determinations should be performed and HOCl concentration calculated. Where chlorination is the only method of treatment, free available chlorine residuals should be taken in the distribution system daily. In a high infectious hepatitis incidence area, if less than 1.5 ppm free residual chlorine is maintained or if water pH is ever over 8, then at least daily pH and water temperature determinations should be performed and HOCl concentration calculated from Figure 2, Appendix I.

APPENDIX III

DETERMINATION OF CHLORINE CONTACT TIME
IN WATER TANKS⁽¹²⁾

The chlorine contact time in water in storage tanks can be determined, as follows when chlorine is added to the water just before it enters the top of the tank and the tank outflow is at the bottom of the tank:

At least 30 minutes contact time is recommended for adequate disinfection of water. If peak consumption rates, storage tank capacity and tank draw-down are known, the following example can be used to estimate contact time. Assume that a 60,000 gallon storage tank is filled from the top and drawn from the bottom, and that extensive mixing does not occur in the tank. If the tank is constantly full, a 30 minutes contact time can only be assumed if the output rate is 60,000 gallons per 30 minutes (120,000 gallons per hour) or less. If the tank becomes half empty during peak flow periods (either because the input pumps do not kick on till then or because the input flow rate is too low to prevent this draw down), then a 30 minute contact time can only be assumed if the output rate is 30,000 gallons per 30 minutes (60,000 gallons per hour) or less.

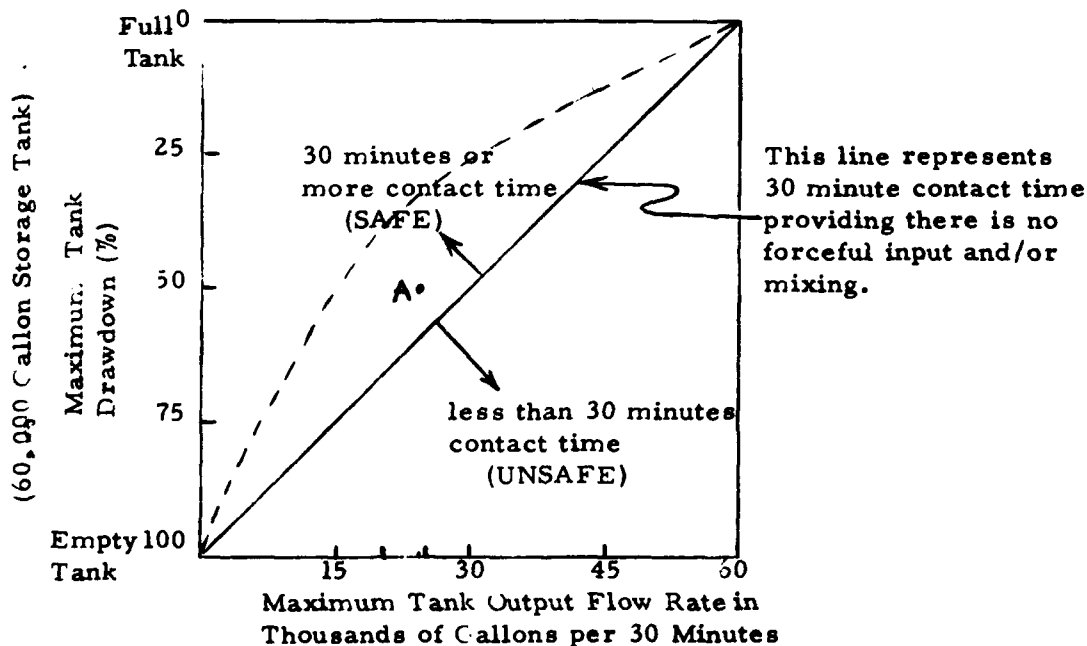


FIGURE I

If the tank is appreciably drawn down, the splash and injection velocity may cause the input water to mix with the outgoing water and move the safe/unsafe boundary curve to the left toward the approximated dashed line above.

An actual example estimating contact time at an Air Force station using the above figure is given below:

Water is pumped into the top of the elevated 60,000 gallon storage tank at a maximum rate of 48,000 gallons per hour. The filling pumps automatically kick on when the water level in the elevated tank is drawn down one-ninth of the way, i.e., when approximately 6,600 gallons have been drawn out. Water flows by gravity from the bottom of the elevated storage tank to the plant at a maximum flow rate, recorded in the past six months, of 24,000 gallons per hour. From the plant it flows usually by gravity to the distribution system. At this flow rate there is over one hour contact time for disinfection in elevated tank. At twice this flow rate (48,000 gallons per hour) there is at least a half-hour chlorine contact time, excluding splash and injection velocity.

As a further example at 24,000 gallons per hour tank output flow rate, if the tank is allowed to become 1/2 empty, chlorine contact time will fall (Point A on Figure 1) into the questionable area i.e. if there is much splash from the input, contact time may be less than 30 minutes.

APPENDIX IV

CALCULATION OF CHLORINE DOSE AND COST

One hundred pounds of calcium hypochlorite $\text{Ca}(\text{OCl})_2$ containing 70% available chlorine (federal stock number 6810-255-0472) costs \$18.80 and will chlorinate 8.4 million gallons of water to, for example, 1 ppm or 4.2 million gallons to 2 ppm if the water has no chlorine demand. This is shown using the following formula:

$$\text{Number of gallons of water to be treated} = \frac{\left(\frac{\text{pounds of calcium hypochlorite required}}{\text{ppm desired}} \right) (10,000) \left(\frac{\% \text{ available chlorine}}{\text{in hypochlorite}} \right)}{(8.34)}$$

$$= \frac{(100)(10,000)(70)}{(1)(8.34)}$$

$$= 8,400,000 \text{ gallons}$$

For example, at Cigli Air Base, Turkey, where chlorination of water to 1.5 ppm free available chlorine is the only method of treatment, records were reviewed to obtain the average monthly amount of water used and calcium hypochlorite required. An average of 20 million gallons of water was used and 400 pounds of calcium hypochlorite was required per month. This amount of calcium hypochlorite is slightly more than that calculated by the above formula because the calculation does not take into consideration the chlorine demand of the water, loss of chlorine residual in the distribution system and other losses. The cost of calcium hypochlorite required to chlorinate the water at Cigli Air Base is approximately \$ 75 per month.

has indicated the need for clarification of the original statement.

Present Practice

Since the early part of the twentieth century, when chlorine came into use for disinfecting potable water, there has been discussion of the desirability of maintaining a chlorine residual in water distribution systems. The maintenance of residual chlorine as an antibody in the veins of a water system appears attractive because, under certain conditions, the residual provides some degree of protection against pathogenic organisms which might adventitiously enter the distribution pipes. During World War II the practice of maintaining or seeking to maintain residual chlorine in water in distribution systems became fairly widespread, particularly in military establishments. Since the war there has been an increase in the number of towns and cities that maintain residuals in their distribution systems.

There has been little uniformity of practice with regard to the type and amount of residual maintained. In some systems the residual has been free available chlorine and in others it has been combined available chlorine. Sometimes the residual levels are allowed to rise and fall through a wide range as the demand for water changes. Occasionally operators attempt to maintain residuals in all parts of the system, but more often they are satisfied if residuals can be found in pipes through which water is actively circulating.

Basic Considerations

One fundamental fact is central to all others in this matter: the only stable chlorine residual is that developed in a chlorine-demand-free water. The production of essentially chlorine-

demand-free water, however, has no public health justification. Virtual bacteriological sterility can be achieved by chlorination of otherwise potable waters with lower concentrations than would be required for the complete satisfaction of the demand-producing substances. Therefore, in ordinary practice all waters treated to meet drinking-water standards contain minute concentrations of substances that react slowly with chlorine in dilute solution so that an initial chlorine residual tends to disappear as the water flows through the distribution system. The inner surfaces of the distribution system itself will also exert a chlorine demand, which can initially be satisfied only by prolonged and relatively heavy chlorination. In order to maintain a trace of residual chlorine in the water reaching the most distant consumer, therefore, the initial chlorine residual must be high enough to offset the demands of the water and also to supply, at the outset of the operation, the demand of the water-contact surfaces. To maintain a residual while avoiding high initial concentrations rechlorination might be applied at intervals throughout the system in a manner analogous to the use of pumping stations to offset friction losses in long pipelines.

Combined chlorine residuals can be maintained within a distribution system much more easily than can free chlorine residuals. The combined residuals, however, are such relatively weak disinfectants that it is questionable whether the two types of treatment should be considered analogous or even comparable unless the combined residuals used are 10-20 times the usual values for free residuals.

The physical and technical difficulties of maintaining residual chlorine throughout a distribution system vary

APPENDIX V (64)

Maintaining a Trace of Residual Chlorine in Water Distribution Systems —NAS-NRC Statement—

A report prepared for the Subcommittee on Water Supply of the Committee on Sanitary Engineering and Environment of the National Academy of Sciences-National Research Council, Washington, D.C.

The question whether or not it is universally desirable, as a matter of policy, to maintain residual chlorine in water in distribution systems operated by the United States military services

was presented to a committee of the National Research Council (NAS-NRC) in 1953. A statement of the conclusions reached was published Oct. 7, 1955. Subsequent comment

greatly, depending on the physical layout of the system. A residual level which may be maintained with relative ease in a compact distribution system with good circulation may be difficult to attain in an attenuated system. These physical differences seem to preclude the enunciation of a single standard of practice.

Residual chlorine in the concentrations routinely employed in water utility practice, will not ordinarily disinfect any sizable amount of contaminating material entering the system, though this will depend on the amount of dilution occurring at the point of contamination, on the type and concentration of residual chlorine, and on the time-of-flow interval between the point of contamination and the nearest consumer. For this reason, a very much higher than normal residual is indicated as an emergency procedure during periods when pressure in parts of the system may fall to a low or even negative value, for example, periods of unusually heavy fire draft, broken mains, floods, or extensive reconstruction or rehabilitation. Such periods of need for the high chlorine residual are as a rule relatively short, ranging from a few hours to a few days.

Chlorine as a Warning Device

It has been suggested that residual chlorine be used as a warning device. The presence of detectable residual chlorine throughout the system would signify that no entry of chlorine-consuming material had occurred. Conversely, a sharp drop in or disappearance of residual chlorine would signal immediate need for the institution of an emergency chlorination regime, with a follow-up sanitary survey to locate the portal of entry of the contamination.

The value of this suggestion depends on the type of residual maintained and is directly proportional to the frequency of the sampling, the number of sampling points, and the extent of knowledge of the normal variations in residuals at the sampling points. A program involving the use of residual chlorine in amounts which on disappearance would serve as a warning of unusual contamination would entail considerable cost. In well-designed distribution systems covered by adequate plumbing codes and competent inspection, the danger of back-siphonage and cross-connection is minimal. Even where these standards are not met, under ordinary circumstances the use of residual chlorine as a warning device is not considered necessary nor very practicable.

Conclusions

In view of the factors discussed above it is the opinion of the NAS-NRC that the establishment of a universal standard for maintaining residual chlorine in water in distribution systems is not desirable. Due to the wide variation in circumstances encountered in the different types of military installations and activities, it is the opinion of the NAS-NRC that the best policy to follow with regard to this matter is to decide what should be done only after all the factors pertinent to a particular local situation or type of operation have been carefully reviewed.

It has been noted that many water systems are able continuously to distribute a safe potable water without maintaining residual chlorine in water in the distribution system. In general such systems are characterized by the excellence of their sanitary design and by the thoroughness and competence

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CHLORINE RESIDUAL MAINTENANCE

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of the sanitary control over their operation. It is recognized also that in other circumstances the most practical means of obtaining water quality that meets accepted bacteriological standards may be insistence on sufficient chlorination to maintain a safe residual level in water in the distribution system. However, the NAS-NRC does not consider maintenance of a residual a satisfactory substitute for good design, construction, and supervision of a water distribution system, nor does it feel that the presence of a residual in

the system constitutes a guarantee of water potability. Routine bacteriological analysis at representative points throughout the distribution is the most significant measure of water safety.

The NAS-NRC has therefore recommended against establishment by the military services of a standard of practice calling for universal maintenance of distribution-system residuals. It has had no intention of setting up rules for civilian health agencies, or of denying that such residuals are useful under many conditions.

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13. ABSTRACT Military age personnel, who were reared on water and food which were rigidly separated from human fecal contamination and/or which were extensively processed to kill all pathogenic organisms, are susceptible to a long period of non-effectiveness due to hepatitis infection. This troop non-effectiveness can only be prevented by continuation of such separation and/or such processing of "oral consumables". This may be expensive in some countries. Close monitoring; securing a bacterial free water source; plus chlorination of the water to 0.4 ppm HOCl at the treatment site after 30 minutes contact time appear to be an inexpensive but usually adequate method for the temporary processing of water to prevent spreading of hepatitis by the water route. If the source water or the distribution system is bacterially contaminated, other measures are necessary. These are reviewed. This chlorine level is acceptable to most consumers for most purposes if phenols or other taste/odor threshold lowering agents are not present. When a significant percentage of troops are likely to drink unauthorized water, measures should be taken to reduce this percentage. Causes for troops consuming unauthorized water are reviewed.		

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